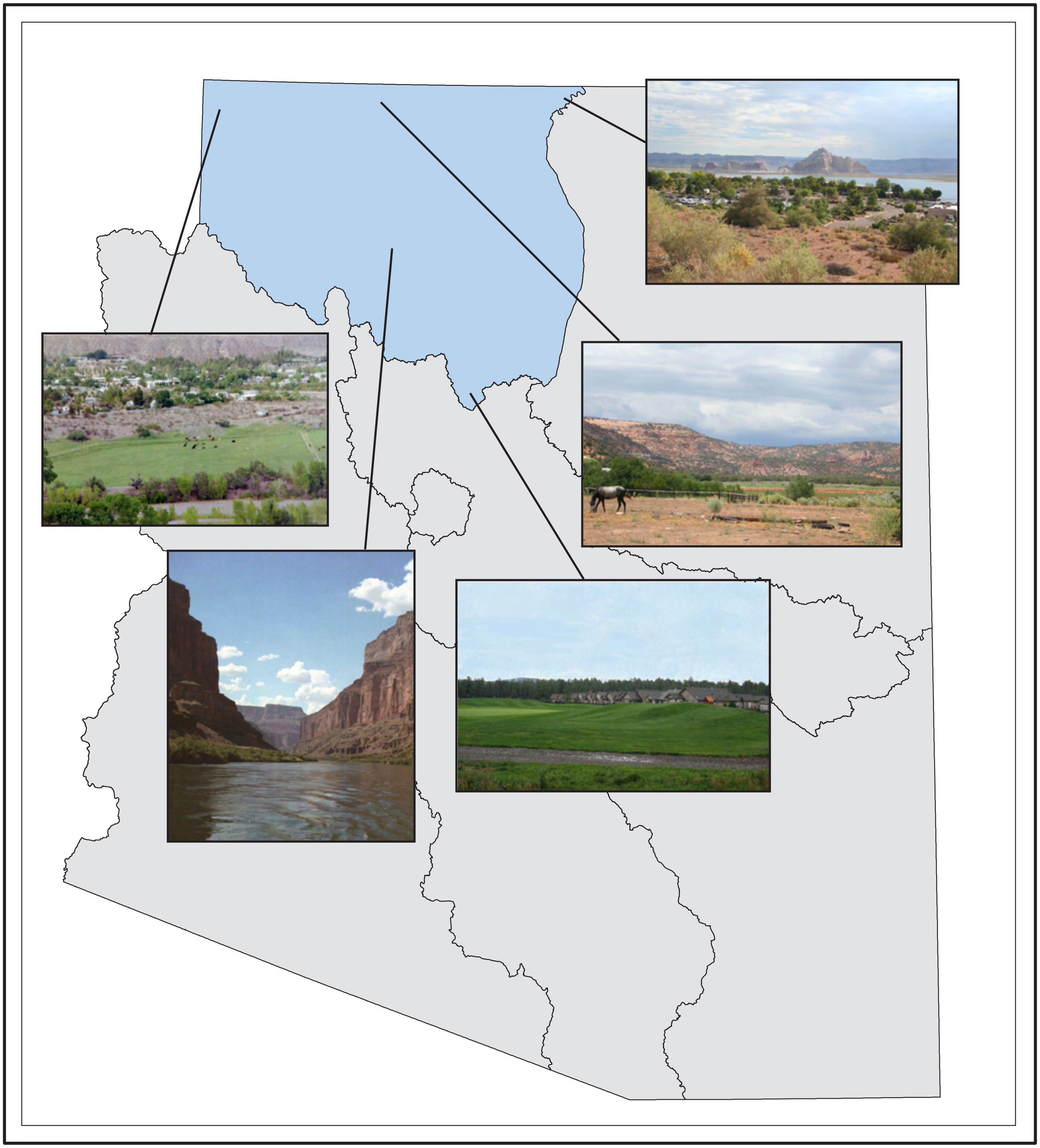
ARIZONA WATER ATLAS
VOLUME 6
WESTERN PLATEAU PLANNING AREA



Arizona Department of Water Resources
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ARIZONA WATER ATLAS
VOLUME 6 - WESTERN PLATEAU PLANNING AREA

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Preface

Volume 6, the Western Plateau Planning Area, is the sixth in a series of nine volumes that comprise the Arizona Water Atlas. The primary objectives in assembling the Atlas are to present an overview of water supply and demand conditions in Arizona, to provide water resource information for planning and resource development purposes and help to identify the needs of communities.

The Atlas divides Arizona into seven planning areas (Figure 6.0-1). There is a separate Atlas volume for each planning area, an introductory volume composed of background information, and an executive summary volume. "Planning areas" are an organizational concept that provide for a regional perspective on supply, demand and water resource issues. A complete discussion of Atlas organization, purpose and scope is found in Volume 1. Also included in Volume 1 is general background information for the state, a description of data sources and methods of analysis for the tables and maps presented in the Atlas, and appendices that provide information on water law, management and programs, and Indian water rights claims and settlements.

There are additional, more detailed data available to those presented in this volume. They may be obtained by contacting the Arizona Department of Water Resources (Department).

6.0 Overview of the Western Plateau Planning Area

The Western Plateau Planning Area is composed of six groundwater basins located in northwestern Arizona. About half of the planning area lies in the part of Arizona north of the Colorado River referred to as the "Arizona Strip". The planning area contains large tracts of federally protected lands including almost all of Grand Canyon National Park. Elevation ranges from over 12,000 feet on the San Francisco Peaks to about 1,200 feet at Lake Mead. Parts of Coconino County (46% of the county) and Mohave County (38% of the county) are contained within the planning area. There are four Indian reservations including the Havasupai, Hualapai, Kaibab-Paiute and Navajo Indian Reservations located within the planning area.

The planning area is relatively sparsely populated. The 2000 Census planning area population was approximately 17,200 with basin population ranges of just 12 in the Shivwits Plateau Basin to over 9,100 in the Coconino Plateau Basin. Colorado City is the largest community with about 3,334 residents in 2000. Other population centers include Williams, Fredonia, Grand Canyon Village and the Beaver Dam/Littlefield area.

An average of over 8,800 acre-feet of water is used annually in the planning area for agricultural, municipal and industrial uses (cultural water demand). Of this total demand, approximately 5,100 acre-feet is from well pumpage, 3,500 acre-feet is from surface water diversions and almost 300 acre-feet is effluent reuse. The agricultural demand sector is the largest with approximately 4,500 acre-feet of demand a year – 51% of the total demand. The municipal sector demand is about 3,400 acre-feet a year and industrial demand is about 900 acre-feet a year.

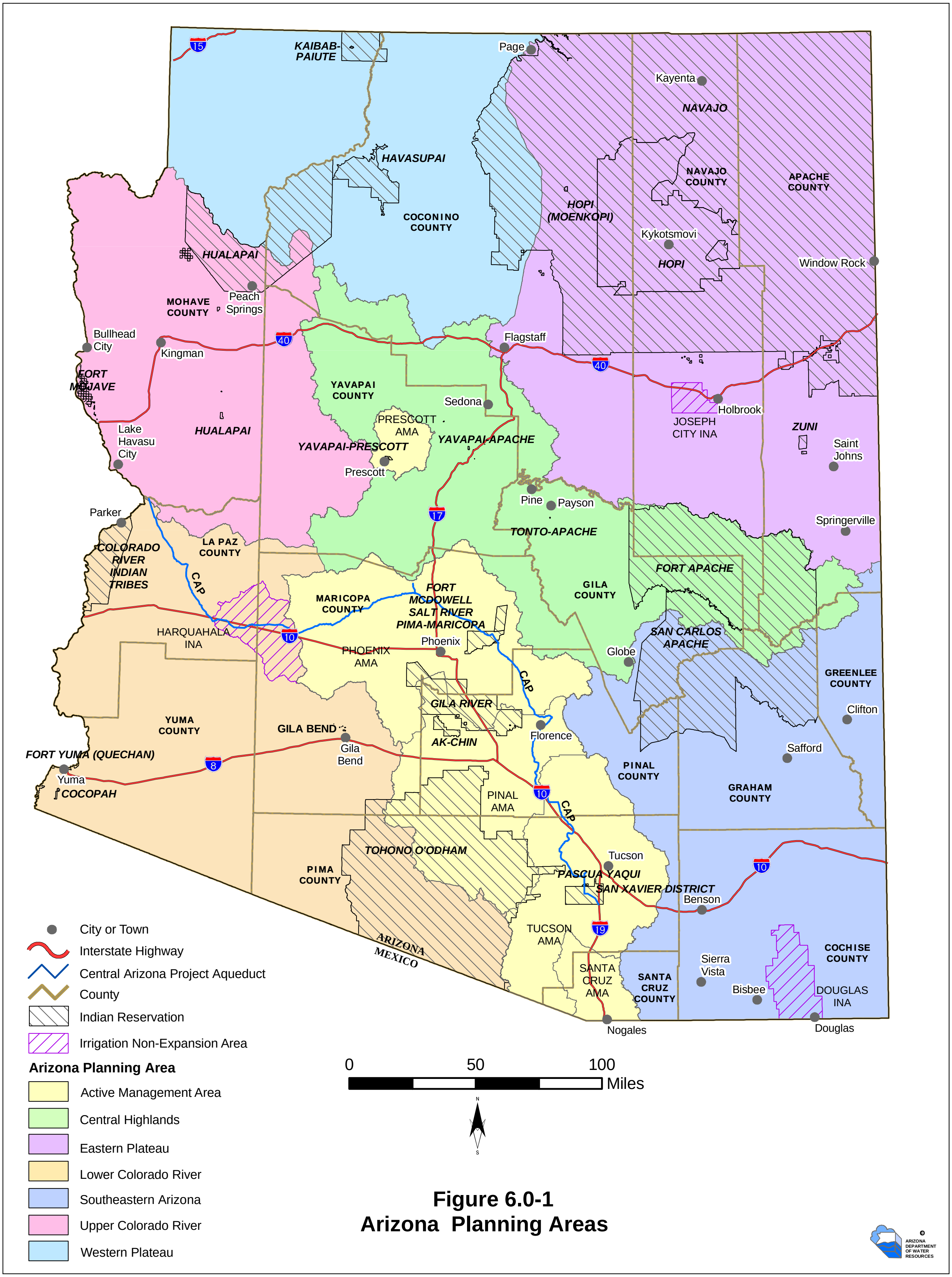


Figure 6.0-1
Arizona Planning Areas

6.0.1 Geography

The Western Plateau Planning Area encompasses about 13,700 square miles and includes the Coconino Plateau, Grand Wash, Kanab Plateau, Paria, Shivwits Plateau and Virgin River basins. Basin boundaries, counties and prominent cities, towns and places are shown in Figure 6.0-2. The planning area is bounded on the north by the State of Utah, on the east by the Eastern Plateau Planning Area, on the south by the Central Highlands and Upper Colorado River planning areas and on the west by the State of Nevada (Figure 6.0-1). The planning area includes parts of three watersheds, which are discussed in Section 6.0.2. The Kaibab-Paiute Indian Reservation (188 square miles) and the Havasupai Indian Reservation (294 square miles) are located entirely within the planning area. In addition, the western portion of the Navajo Indian Reservation (1,177 square miles) and the northeastern portion of the Hualapai Indian Reservation (741 square miles) are located within the planning area (Figure 6.0-1).

Almost all of the planning area is within the Plateau Uplands physiographic province characterized by horizontally stratified sedimentary rocks that have eroded into numerous incised canyons and high desert plateaus (See Volume 1, Figure 1-2). The extreme western part of the planning area, encompassing the western portions of the Virgin River and Grand Wash basins, extends into the Basin and Range Lowlands physiographic province, which is characterized by northwest-southeast trending mountain ranges separated by broad alluvial valleys. The basin with the largest elevational range in the planning area occurs in the Coconino Plateau Basin with ranges from 1,400 feet where the Colorado River exits the Coconino Plateau Basin in the Grand Canyon to over 12,000 feet in the San Francisco Peaks at the southeastern edge of the basin.

A unique geographic feature of the planning area is the Grand Canyon, primarily incised by the Colorado River and its tributaries over a 5-6 million year period. The average depth of the canyon is 4,000 feet over its entire 277 miles, and 6,000 feet at its deepest point, with an average width of 10 miles. The geologic record at the Grand Canyon is unique in the variety of rocks and their clear exposure in the canyon walls. Nearly half of the earth’s 4.6-billion-year history is displayed in the Canyon (NPS, 2005).

Most rocks in the Grand Canyon date from the Paleozoic Era (550-250 million years ago) but there are scattered remnants of Precambrian Vishnu Schist as old as 2 billion years old found in the inner gorge. With the exception of Kaibab limestone, younger Mesozoic and Cenozoic rocks (250 million years old to the present) are largely missing at Grand Canyon, having been either never deposited or worn away. The different rock layers in the canyon respond differently to erosion leading to the Canyon’s distinctive shape (NPS, 2005). Lava flows ranging in age from 1,000 to 1 million years old are found in the western part of the Canyon.

The Grand Canyon and the Colorado River form a significant physical barrier between the Arizona Strip and the rest of the planning area and the state. Highway 89A at Navajo Bridge and Highway 89 at Glen Canyon Dam are the only highways that span the Colorado River and link the Arizona Strip to the rest of the state. By contrast, there are a number of road links between the Arizona Strip and Utah. As a result, the Arizona Strip has strong historic, cultural and economic ties to Utah.

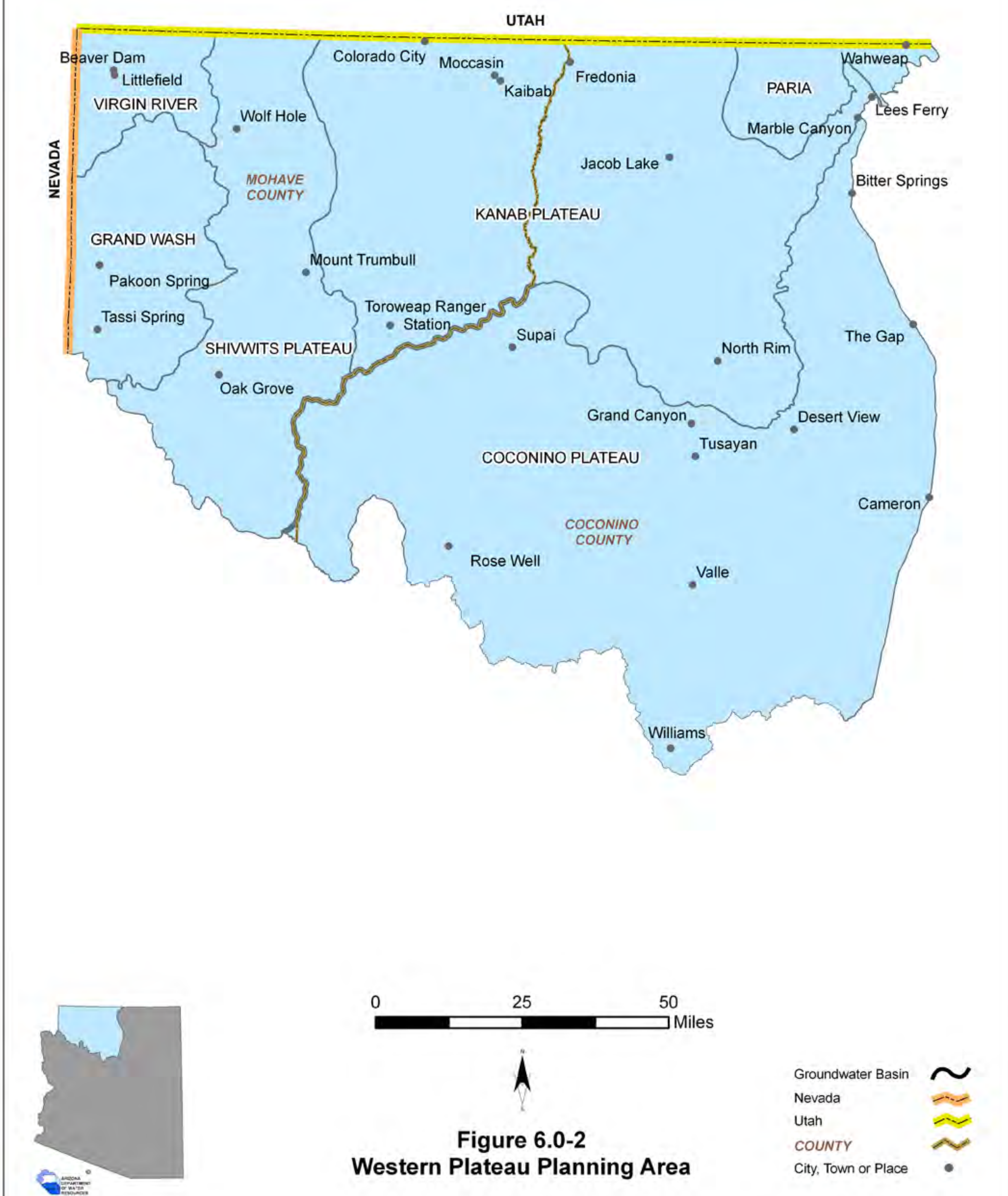


Figure 6.0-2
Western Plateau Planning Area

South and east of the Colorado River, the Coconino Plateau marks the southern edge of the Colorado Plateau which covers 130,000 square miles across southeastern Utah, northern Arizona, northwestern New Mexico, and western Colorado. The Coconino Plateau stretches east toward the Colorado River surface water divide and south to the Mogollon Rim, which is less well defined to the northwest. The Coconino Plateau groundwater basin boundary is considered to be north of the Rim. Most of the Coconino Plateau is above 5,000 feet in elevation and consists of low hills, mesas, broad valleys and lava flows in the southern portion. The Plateau is defined by large elevational changes along its margins including the south rim of the Grand Canyon (Bills, et al. in press).

Other significant geographic features are numerous high plateaus, steep cliffs, deeply incised canyons and few surface water features. In the extreme northwest corner of the planning area, the Virgin River cuts through the Beaver Dam Mountains creating the spectacular Virgin River Gorge. West of the gorge, the topography abruptly changes to a broad alluvial valley with numerous washes that drain the upland and mountain areas. The Virgin Mountains, south of the river, form the southwest edge of the Colorado Plateau.

6.0.2 Hydrology[1]

Groundwater Hydrology

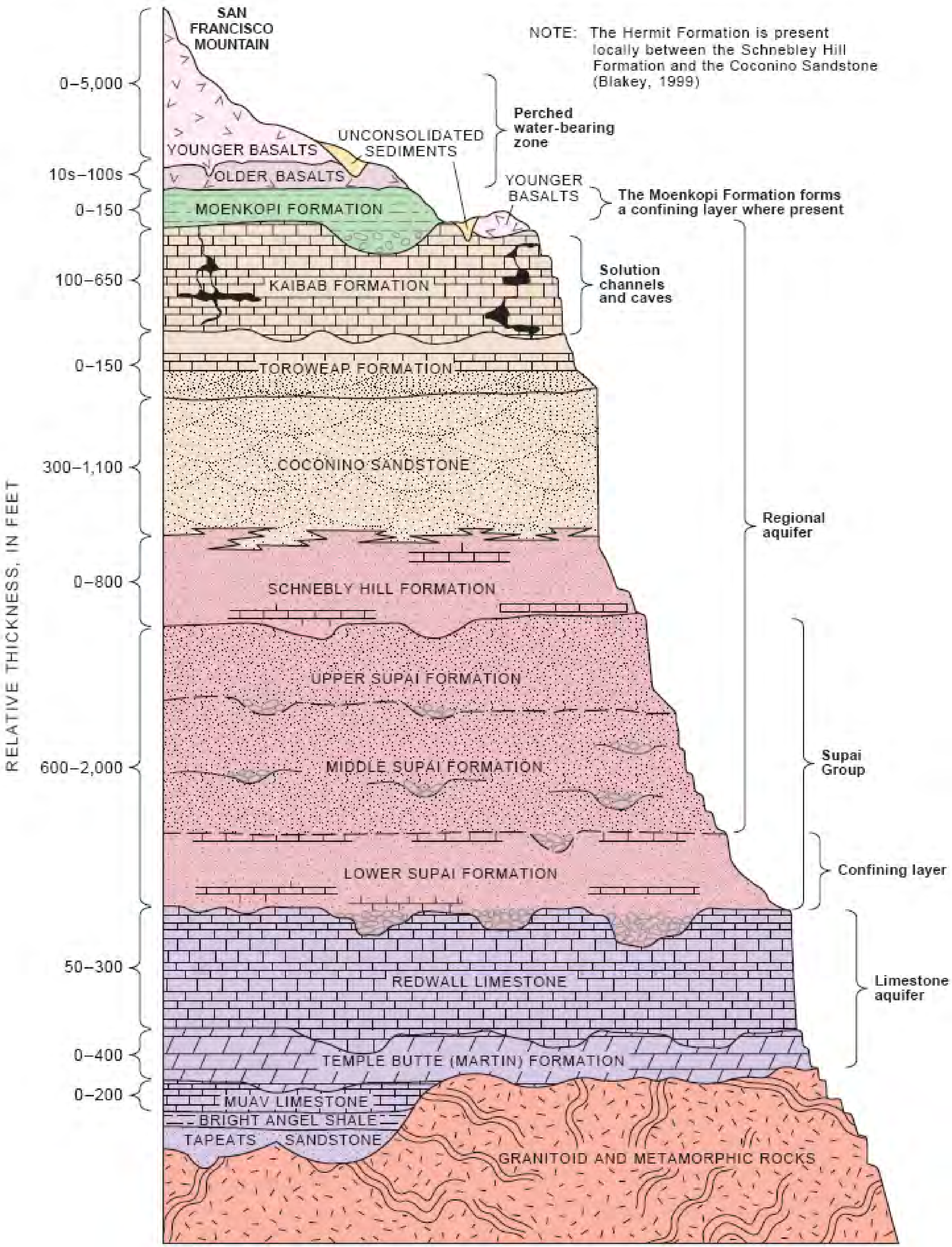
The Western Plateau Planning Area is generally characterized by relatively flat-lying alternating sequences of sandstones, limestones and shales. Faults and monoclines control groundwater movement along the regional gradient. The westernmost basins contain basin-fill sediments composed of silt, sand and gravel. Relatively few hydrologic studies have been conducted in the planning area and general hydrologic characteristics are described below.

<u>Coconino Plateau Basin</u>
The Redwall-Muav (R-aquifer or limestone aquifer) is the primary water-bearing unit of the Coconino Plateau Basin. The Kaibab, Coconino and Supai formations comprise the regional Coconino Aquifer (C-aquifer) that overlies the R-aquifer. The Moenkopi and Chinle formations, volcanic rocks and unconsolidated sediments overlie the C- and R-aquifers and provide locally important sources of water. A stratigraphic section of the Coconino Plateau that illustrates the relationship between these various units is shown on Figure 6.0-3. Perched aquifer zones in association with volcanic rocks occur primarily in the central and southern part of the basin and in consolidated sedimentary rocks west and northwest of the volcanic fields. These perched aquifers are dependent on recharge from precipitation and runoff and may be undependable water supplies. An exception is the "Inner Basin Aquifer" of the San Francisco Peaks where the water-bearing zone is contained in glacial outwash and volcanic rocks and is used by the City of Flagstaff as a water supply (USBOR, 2006).

The R-aquifer underlies the entire Coconino Plateau Basin at a depth of greater than 3,000 feet below land surface in most areas (Bills, et al., in press). Relatively few wells have been completed

[1] Except as noted, much of the information in this section is taken from the Arizona Water Resources Assessment, Volume II, ADWR (August, 1994).

Figure 6.0-3 Generalized stratigraphic section of the Coconino Plateau, Arizona (Bills and Flynn, 2002)



in the R-aquifer in the basin due to its extreme depth. In the northeast part of the basin the R-aquifer is in partial hydraulic connection with the C-aquifer through faults and other fractures. Shale units within the R-aquifer impede downward flow. Lateral movement of groundwater occurs through fracture zones and solution cavities and is generally northward toward the Grand Canyon where springs discharge along the Little Colorado and Colorado Rivers and Havasu Creek. Regional structures in the basin, including the Mesa Butte Fault and the Cataract syncline, direct flow to major discharge areas on the lower Little Colorado River and in Cataract Canyon (USBOR, 2006). Water quality is generally good in the basin but poor locally where there is leakage from overlying units or other factors.

Water levels in wells are typically quite deep in the basin and yields in the R-aquifer are relatively low depending on the occurrence of fractures, faults and solution channels. Tusayan's water supply plan reports water level depths of 2,347 and 2,425 feet in two system wells with well yields of 65-80 gallons per minute (gpm) (HydroResources, 2007). While water has been found in perched aquifers near Williams at depths less than 950 feet deep, yields from these more shallow wells are generally less than five gallons per minute. At Williams, three of the four water system wells are drilled to depths exceeding 3,500 feet below land surface. Water level depths in these wells are between 2,740 and 2,875 feet. Water in the deepest of the Williams wells is of poor quality with elevated metals concentrations, including arsenic, and high corrosivity (City of Williams, 2007).

Widely-spaced faults and monoclines affect the movement of groundwater in the region. Local flow characteristics are poorly understood because of the complex geologic structure and because aquifer depths limit exploratory drilling and testing. The varying chemistry of springs and residence time for groundwater discharge suggests that water discharging from the R-aquifer is from many different recharge areas and follows different flow paths (USBOR, 2006).

The C-aquifer, consisting of hydraulically connected sandstones, limestones and shales occurs primarily in the far eastern and southeastern portion of the basin. Although perched zones occur, it is largely drained of water in the rest of the basin, coincident with the northeast-southwest trending Mesa Butte Fault (Bills et al., in press). Infiltration of precipitation through volcanic rocks and the Kaibab Formation is the primary source of recharge to the C-aquifer. Groundwater movement through the water-bearing units of the C-aquifer is likely through faults and fractures (USBOR, 2006). In the northeastern portion of the Coconino Plateau basin, groundwater moves relatively rapidly from the C-aquifer to the R-aquifer through solution channels and fractures. Within the R-aquifer, groundwater moves along the northern part of the Mesa Butte Fault and other faults and discharges at Blue Springs on the Little Colorado River (Montgomery, et al., 2000). The Blue Springs area is considered the primary groundwater drain from the Little Colorado River Basin, although the primary source of the water is not well known (Hart, et al., 2002). Water quality in the upper and middle parts of this aquifer is good, but generally degrades due to salts at increasing depths.

<u>Grand Wash Basin</u>

The Grand Wash Basin, in the western part of the planning area, is located along the boundary of the Plateau Uplands and Basin and Range provinces. Groundwater is found in recent stream alluvium, basin fill, and sedimentary rocks of the Muddy Creek Formation and underlying Cottonwood Wash

Formation. The Muddy Creek Formation is composed of siltstones, sandstones and conglomerates with interbedded basaltic lavas in the northern part of the basin. The Cottonwood Wash Formation is composed of sandstones and siltstones. Only 12 wells are registered in the basin and two of these have depths that range from about 20 feet to over 500 feet (see Figure 6.2-6).

In the southwestern corner of the basin, surface water from Lake Mead has saturated adjacent rocks and deposits in quantities greater than pre-lake conditions. This saturated zone is estimated to extend less than half a mile inland from the lake. Recharge from precipitation or local surface runoff is small. There is a relatively well-defined basin fill aquifer interbedded with basalt flows between Grand Wash and Gyp Wash (located west of the Grand Wash Cliffs, see Figure 6.2-1). This aquifer is underlain by the Muddy Creek Formation which is a confining unit in the area, preventing the downward movement of water. This area was identified as favorable for groundwater development in a geohydrologic reconnaissance study of Lake Mead National Recreation Area conducted by the USGS (Bales and Lacy, 1992). Water quality is generally good in the basin although total dissolved solids concentrations equal or exceeds drinking water standards at several springs.

Kanab Plateau Basin

The Kanab Plateau Basin is characterized by high plateaus, plains and incised canyons. The basin contains a flat-lying to gently sloping sequence of alternating sandstones, limestones and shales. Groundwater is found in several aquifers composed of these formations. Water bearing units in the vicinity of Pipe Spring National Monument include alluvium, Navajo Sandstone, the Kayenta and Moenave Formations, and the Shinarump Formation (Truini et al., 2004). The two basin hydrographs available for the study period (See Figure 6.3-7) are wells completed in the Kayenta Formation at Moccasin, with a recent water level of 87 feet below land surface, and one in "sedimentary rock" south of Fredonia and north of Kanab Creek with a recent water level of 611 feet. These aquifers are generally isolated and not hydraulically connected. Within the aquifers, faults act as conduits for vertical and lateral groundwater movement. Major faults include the Toroweap and Sevier faults. Groundwater also occurs in recent stream alluvium, including the Cane Beds area west of Moccasin. The median well yield from ten large wells in the basin was 70 gpm. Elevated levels of total dissolved solids and lead have been measured at some sites although water quality is generally good for most uses.

Paria Basin

The geologic structure of the Paria Basin is typical of the Colorado Plateau with a gently-sloping sequence of limestone, sandstone and shale formations. The principal aquifer in this basin is the N-aquifer composed of Navajo Sandstone and the Kayenta and Moenave Formations. Groundwater development is relatively small with only 12 wells registered in the basin. Well yields vary from 30 to 1,400 gallons per minute, with the largest yields coming from wells completed in sedimentary rocks. Water levels in wells are relatively deep, ranging from about 480 feet to 1,500 feet deep. In some places in the Paria Basin, precipitation collects in sand deposits in limited quantities and may be recovered from shallow wells (Bush and Lane, 1980). Groundwater movement is generally from south to north with discharge at springs in the Paria River Canyon. However, some groundwater moves south toward the Vermilion Cliffs, which form the southern basin boundary. Arsenic concentrations above the drinking water standard have been measured at a number of wells in the Wahweap area (see Table 6.3-7).

Figure 6.0-4 Geologic cross section of the Shivwits Plateau, Kanab Plateau and Coconino Plateau Basins (modified from Billingsley and Welmeyer, 2003)

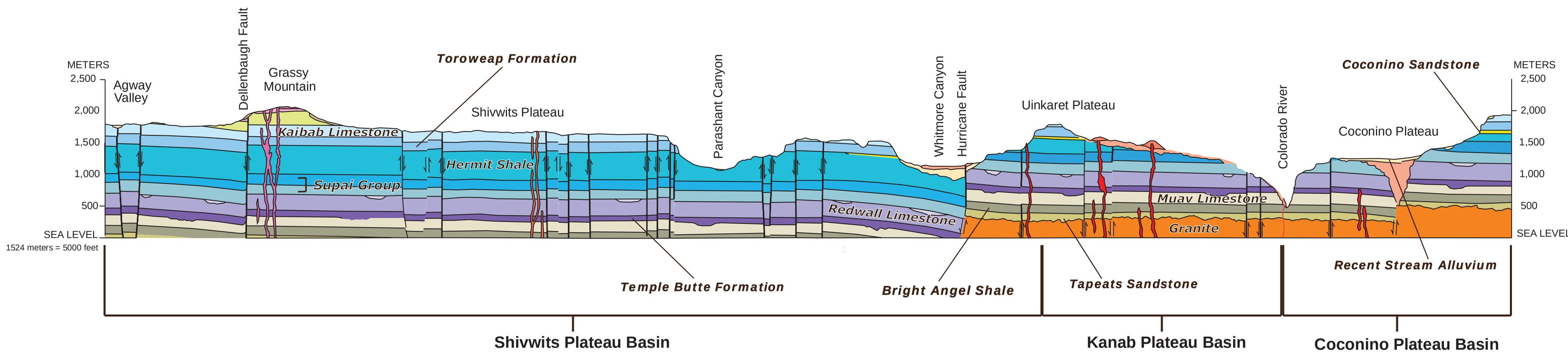


Figure 6.0-4 shows a cross section of the geology in the Shivwits Plateau, Kanab Plateau and the western portion of the Coconino Plateau basins. The cross section begins in the west-central portion of the Shivwits Plateau Basin (T33N, R12W) and proceeds at a southeastern diagonal across the Shivwits Plateau and Kanab Plateau basins, ending just across the Colorado River in the Aubrey Cliffs in the Coconino Plateau Basin (T32N, R7W). The cross section is a general indication of the location of the water bearing units and their depth and thickness in this particular area. The diagram also shows the impact of the Hurricane Fault on the depth and occurrence of the geologic units.

Shivwits Plateau Basin

Most of the Shivwits Plateau Basin covers a high plateau with elevations of 4,000 to 6,000 feet. The basin contains an alternating sequence of limestones, sandstones and shales with alluvial sands and gravels along larger washes and canyons. There are only 18 registered wells in the basin. Recent water levels in wells range from 10 feet to over 960 feet (see Figure 6.5-7). Stream alluvium is the major aquifer in the basin with well yields ranging from 2 to 35 gallons per minute. A number of dry wells have reportedly been drilled into the sedimentary rocks but some encountered water in faults and fractures. Groundwater recharge occurs from infiltration of rainfall and snowmelt. Water from springs and seeps tends to be of slightly better quality than well water, although arsenic at levels that equal or exceed drinking water standards has been detected in one spring.

Virgin River Basin

Located in the northwestern corner of Arizona, the Virgin River Basin extends into Utah and Nevada. It contains a broad alluvial valley in the western half of the basin and the relatively high elevation Beaver Dam and Virgin Mountains along its southern and eastern boundary. Principal aquifers are basin fill in the Virgin River Valley and Beaver Dam Wash, and the Muddy Creek Formation. The eastern, mountainous part of the basin is composed of sedimentary and igneous rocks with little groundwater development.

The basin fill aquifers are composed of a younger floodplain unit and an older underlying unit of semi-consolidated silts, sands, gravels and boulders. In the Virgin River Valley, the basin fill aquifer contains floodplain and terrace alluvium southwest of Littlefield and includes the alluvial-fan deposits of the Virgin Mountains. Groundwater is unconfined and flows toward the southwest. In Beaver Dam Wash, the basin fill aquifer is largely isolated from other water bearing units in the basin and is unconfined. Groundwater flow is toward the Virgin River Valley.

The Muddy Creek Formation is a series of siltstones, sandstones and conglomerates that is utilized as a water supply in the western part of the basin and by the City of Mesquite, Nevada adjacent to the basin along Interstate 15 (Black and Rascona, 1991). It is several thousand feet thick in places and forms the land surface over much of the basin north of the Virgin River. The Muddy Creek Formation is underlain by saturated Paleozoic carbonate rocks. South of the Virgin River, alluvial deposits from the Virgin Mountains overlie the Muddy Creek Formation. Fault and fracture zones in this formation control groundwater movement and may have groundwater development potential (Dixon and Katzer, 2002).

Between Littlefield and the Virgin River Mountains and south of the Virgin River, a shallow, basin fill aquifer overlies a limestone formation known locally as the “Littlefield Formation”. Few wells are completed in the shallow aquifer but a number of springs emanate from groundwater flowing over or through the Littlefield formation (Black and Rascona, 1991).

Well yields range widely in the basin, as shown on Table 6.6-6, from a reported 10 gpm in the Virgin River basin fill aquifer to over 5,000 gpm during a pump test in the Beaver Dam Wash basin fill aquifer (Black and Rascona, 1991). The median yield from 53 large diameter wells completed in the basin is 650 gpm. Water quality ranges from very good to poor due to high concentrations of arsenic, chloride, sulfate and total dissolved solids. Salt concentrations in groundwater increase downstream in the floodplain area along the Virgin River.

Surface Water Hydrology

The U.S. Geological Survey (USGS) divides and subdivides the United States into successively smaller hydrologic units based on hydrologic features. These units are classified into four levels. From largest to smallest these are: regions, subregions, accounting units and cataloging units. A hydrologic unit code (HUC) consisting of two digits for each level in the system is used to identify any hydrologic area (Seaber et al., 1987). A 6-digit code corresponds to accounting units, which are used by the USGS for designing and managing the National Water Data Network. There are portions of three watersheds in the planning area at the accounting unit level: the Little Colorado River; the Lower Colorado River, Lees Ferry to Lake Mead; and the Upper Colorado River, Lake Powell Area (Figure 6.0-5). (A very small portion of the Verde River Watershed is located east of Williams and is not discussed in this volume).

The Little Colorado River

The Little Colorado River Watershed extends over a large portion of northeastern Arizona, including most of the Eastern Plateau Planning Area. Within the Western Plateau Planning Area, this watershed covers the eastern portion of the Coconino Plateau Basin from The Gap and Desert View south toward Flagstaff. The Little Colorado River is the major drainage in the entire Coconino Plateau Basin, flowing east to west to join the Colorado River. The only perennial flow in this portion of the planning area is a 13-mile stretch of the Little Colorado River below Blue Springs, which has a discharge of over 101,000 gpm. Blue Springs is the only large spring in the area.

An active gage on the Little Colorado River at Cameron has been in operation since 1947. Flow is highest in the winter at this gage, with a median annual flow of over 138,000 acre-feet. Maximum annual flow at this gage was over 603,000 acre-feet in 1993 (see Figures 6.1-4 and 6.1-5 and Table 6.1-2).

Upper Colorado River, Lake Powell Area

The boundary of the Upper Colorado River watershed in Arizona coincides generally with the Paria Basin boundary. It includes the Paria River Canyon and a small portion of the Kanab Plateau Basin. The Paria River originates in south-central Utah, draining an area of about 1,410 square miles before discharging to the Colorado River north of Lees Ferry. The Paria River and the Colorado River are the only perennial streams in this portion of the planning area. The single streamflow gage in the area is located on the Paria River at Lees Ferry. With 79 years of record, the average annual flow is over 20,000 acre-feet and maximum flow was almost 48,000 acre-feet in 1980. There are two nearby gages on the west side of the Colorado River in the Eastern Plateau Planning Area. The gage below Glen Canyon Dam was installed after dam construction and reflects regulatory/managed releases from Lake Powell. Prior to construction of the dam in 1963, the average flow was about 12.9 million acre feet (maf) per year. The average annual flow at the gage below Glen Canyon Dam is now 8.4 maf. Downstream, flow records at the gage on the Colorado River at Lees Ferry show 20.3 million acre-feet. This gage has been in operation since 1921.

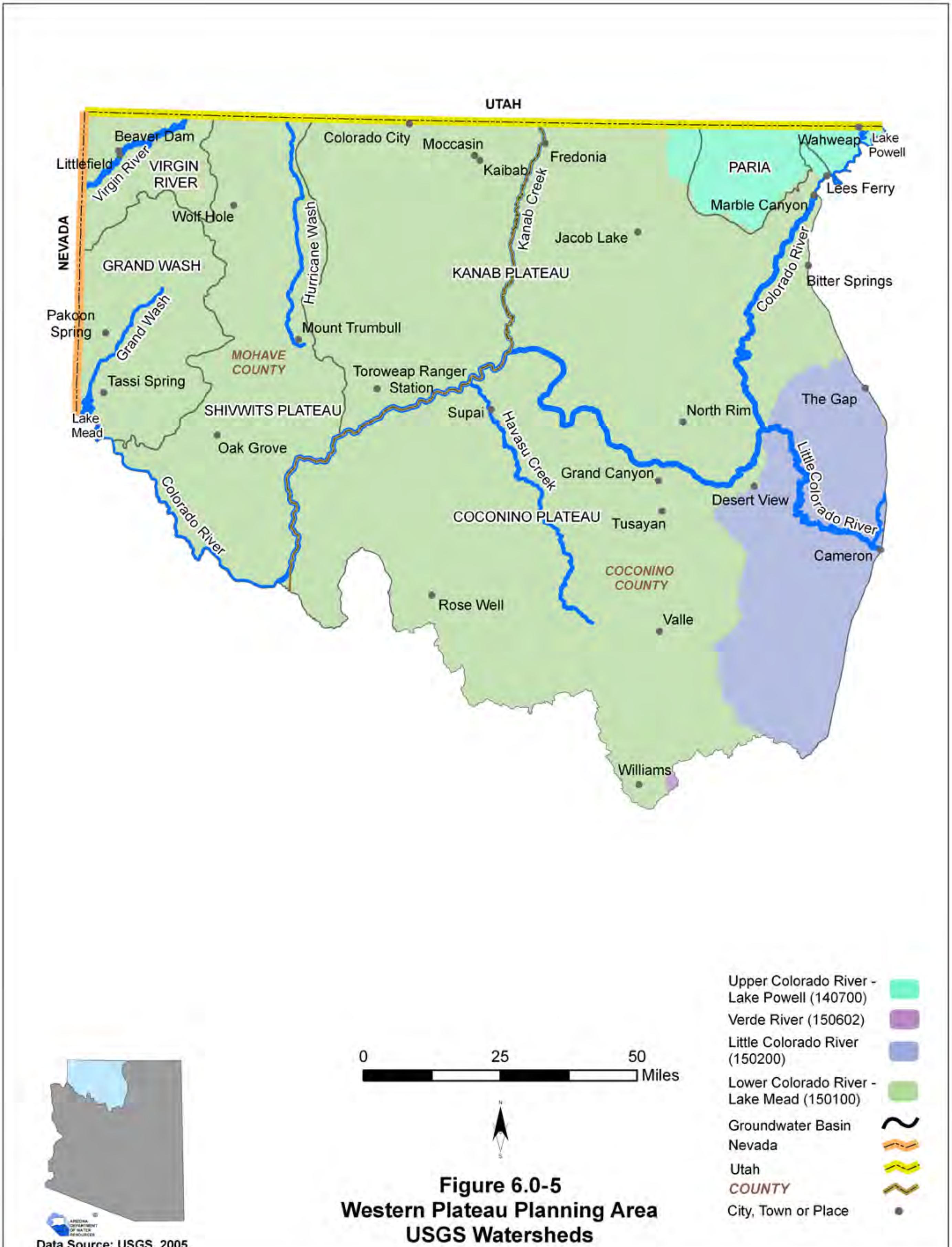


Figure 6.0-5
Western Plateau Planning Area
USGS Watersheds

In May 1983, a heavy snowpack in the Upper Basin of the Colorado River combined with sudden warming and rainfall caused severe flooding along the Colorado River, forcing use of the Glen Canyon Dam spillways for the first time since dam completion in 1964. The total discharge peaked at 92,000 cubic feet per second (cfs) and the reservoir level topped out on July 15th, six feet below the crest of the dam (Hannon, 2003). By contrast, releases from Glen Canyon Dam in July 2007 were 13,100 cfs on average and, due to prolonged drought, the reservoir was at 53% capacity. Since 1999 inflow to Lake Powell has been below average in every year except one (USBOR, 2007a).

Lake Powell provides water storage to meet flow obligations at Lees Ferry under the terms of the 1922 Colorado River Compact. (See Volume 1, Appendix A) The Compact apportioned to the Upper and Lower Basin states the beneficial consumptive use of 7.5 maf of water to each basin annually, measured at the Colorado River at the Compact Point near Lees Ferry. The reservoir has a total storage capacity of 27 maf, generally equivalent to the average annual flow of the Colorado River over a two-year period, making it the second largest reservoir in the country. The Glen Canyon Power Plant consists of eight generating units and provides most of the electrical energy generated by the Colorado River Storage Project. Total generating capacity is 1,296,000 kilowatts (USBOR, 2005).

There are no major springs (>10gpm) in this portion of the planning area although springs reportedly have supported domestic and stock watering uses (Bush and Lane, 1980). The Paria River has been identified as an impaired reach for its entire 29-mile length in Arizona, due to a high concentration of suspended sediments (ADEQ, 2002).

<u>Lower Colorado River, Lees Ferry to Lake Mead</u>
Most of the Western Plateau Planning Area is included in the Lower Colorado River, Lees Ferry to Lake Mead watershed, which extends into the Upper Colorado River Planning Area. The watershed is drained by the Colorado River, which flows southwest from Lake Powell to Lake Mead. There are a number of perennial streams in the Kanab Plateau Basin that flow to the Colorado River including Kanab, Bright Angel, Nankoweap, Shinumo and Tapeats Creeks. None of these streams have flow gages. In the Coconino Plateau Basin, major perennial tributaries are Havasu and Diamond Creeks.

The only other perennial streams in the planning area west of Diamond Creek are the Virgin River, which flows through the planning area from its headwaters in Utah to Lake Mead in Nevada and an approximately one-mile reach of a tributary, Beaver Dam Wash. The Virgin River drains an area of about 6,100 square miles. Prior to construction of Hoover Dam, it flowed to the Colorado River. Now, its lower 20-30 mile former reach has been inundated by the Overton Arm of Lake Mead.

Colorado River
Flow in the Colorado River downstream from Lake Powell is controlled by releases from Glen Canyon Dam, which has significantly impacted flow volumes and historic seasonal variations in flow as mentioned in the previous watershed discussion. There are five streamflow gages along this reach of the Colorado River in addition to three gages in the Lake Powell area. The three

easternmost gages are located on the north side of the river above the Little Colorado River and near Bright Angel Creek (see Figure 6.3-5). The two westernmost gages are located on the south side of the river near Havasu Creek and Diamond Creek (see Figure 6.1-5). The easternmost gages have varying periods of record and show average annual flows of 8.5 to 11.2 maf a year. A gage with 79 years of record, the only pre-dam gage, has the highest mean flow and a maximum flow of 20.5 maf in 1984. The only currently operating downstream gage has a similar flow regime to the gage above the Little Colorado River.

The preceding statistics and the relative uniformity of seasonal flows reflect the controlled releases of water from Glen Canyon Dam (See Tables 6.1-2 and 6.3-2). Prior to construction of the Dam, flow in the Colorado was highly unpredictable with wide year-to-year variability and spring flooding. Operation of the dam for electrical generation requires large water releases with daily and weekly fluctuations and releases during historically low flow seasons. Provisions of the Record of Decision (1996) for the Glen Canyon Dam Final EIS and the Glen Canyon Dam Operating Criteria (1997) set restrictions on daily and hourly flows. The maximum flow may not exceed 25,000 cfs except for beach/habitat-building flows, habitat maintenance flows, or when necessary during above average hydrologic conditions. Minimum flows are restricted to 5,000 to 8,000 cfs depending on the time of day. Further, daily fluctuation limits are 5,000 cfs to 8,000 cfs depending on monthly release volumes. (USBORb, 2007)

A tree-ring-based reconstruction of over 500 years of Colorado River streamflow found as many as eight droughts similar in severity to the 2000-2004 drought period. The reconstruction also suggests that the last 100-year period was wetter than the average for the last five centuries, and that average annual flows regularly vary from one decade to the next by more than one maf. The most severe sustained drought (based on the lowest 20-year average) in the Upper Colorado River basin apparently occurred in the last part of the 16th century. (Meko et al, 2007)

Virgin River and Beaver Dam Wash

Average annual flow in the Virgin River above the Narrows gage is about 92,600 acre-feet. Downstream, the stream gage near Littlefield, with a much longer period of record (72 years), shows an average annual flow of 174,502 acre-feet and a maximum flow of 506,912 acre-feet in 1983. Below the Narrows gage, flow increases downstream to the Littlefield gage and beyond due to springs and groundwater inflow (Dixon and Katzer, 2002). (See Figure 6.6-5 for gage locations)

Older reports indicate that flow in the Virgin River disappeared into the riverbed before the river entered Arizona from Utah and reappeared about five miles above Littlefield due to spring discharge. More recently, the AGFD report that the entire reach within Arizona is perennial (see Figure 6.6-6). Post 1990 gage data and seepage measurements suggest that historical seepage losses to the groundwater system in Utah are no longer occurring. Based on seepage measurements along the Virgin River in Arizona, it appears that between 20 to 30 cfs of Virgin River flow is lost upstream of the Narrows gage in Arizona through infiltration (Cole and Katzer, 2000). Studies estimate that 20 to 50 cfs (14,500 to 36,200 acre-feet per year) reenters the river via springs and groundwater discharge between the Narrows and the Littlefield gage. These springs are collectively referred to as the Littlefield Springs, consisting of eight springs over a distance of seven miles between the two gages (Trudeau, et al., 1983). The springs are difficult to measure because they are located in the Virgin River channel and can only be observed during low flow when the sediment load is near zero (Dixon and Katzer, 2002). Springs support perennial flow in Beaver Dam Wash, which discharges to the Virgin River above the Littlefield gage. These springs collectively discharge over 1,100 gpm.

A number of major springs issue from the Redwall and Muav Limestones and to a lesser extent, the Tapeats Sandstone, in the vicinity of the Colorado River in the Kanab Plateau and Coconino Plateau basins. The largest are Havasu Springs in the Coconino Plateau Basin with a discharge of about 28,500 gpm, and Tapeats Spring in the Kanab Plateau Basin with a discharge of about 18,700 gpm. Havasu Creek is perennial below Havasu Spring, located upstream of the village of Supai, and contains moderate levels of calcium, magnesium and bicarbonate from the springs along its course. Calcium carbonate precipitates out of the spring water, forming travertine deposits along the creek bottom/bed. Roaring Springs, located 3,000 feet below the North Rim, emanates from a cave in the Muav Limestone above the intersection of the Roaring Springs and Bright Angel faults. It has a discharge of almost 2,000 gpm and is the water supply for the North and South Rims of Grand Canyon National Park (USBOR, 2002).

A group of major springs with discharge rates between 11 and 90 gpm are found in the vicinity of Moccasin and Kaibab in the north-central part of the Kanab Plateau Basin. Studies at Pipe Spring National Monument indicate that spring discharge is from a sandstone unit of the Kayenta Formation. Fine-grained sediments below the unit create a confining layer that restricts vertical water movement and forces groundwater to move along bedding planes and fractures in the Navajo Sandstone and the upper unit of the Kayenta Formation. In the monument, discharge at Pipe Spring declined between 1976 and 2003 but increased at Tunnel Spring for reasons that are unclear. The combined spring discharge declined about 0.5 gpm per year between 1986 and 2001 (Truini, et al., 2004).

A handful of major springs are found in the other basins in the watershed. In the Grand Wash Basin, three major springs, (Tassi, Whiskey and an unnamed spring) discharge from the basin-fill aquifer where it overlies a confining unit, the Muddy Creek Formation (Bales and Lacy, 1992). This may be the case with other springs in the basin. The only major spring in the Shivwits Plateau Basin, with a measured discharge of 331 gpm is found at the mouth of Spring Canyon at the Colorado River.

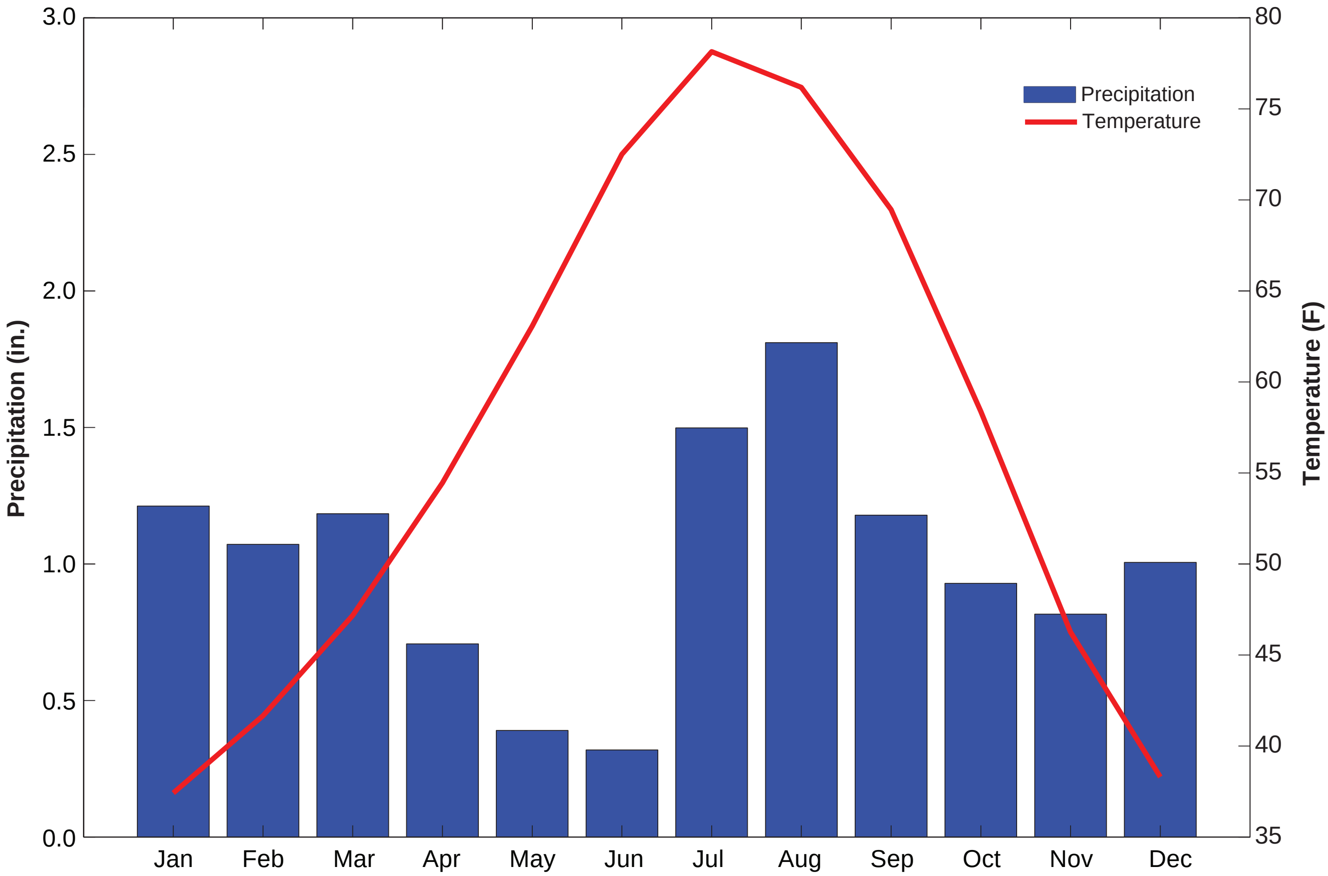
6.0.3 Climate[2]

The average annual temperature of the Western Plateau Planning Area (57.9°F) is somewhat cooler than the statewide average (59.5°F). Average annual precipitation in the planning area is 12.1 inches, the same as the statewide average. Annual totals vary widely across the area, from 6-9 inches at low elevation (less than 5000 ft.) and rain shadow stations such as Wahweap, Fredonia, and Beaver Dam, to greater than 20 inches at Williams and Bright Angel Ranger Station in Grand Canyon National Park. On average, the Western Plateau Planning Area exhibits the bi-modal precipitation pattern characteristic of Arizona (see Figure 6.0-6); however, the northwestern part

[2] Information in this section was provided by Institute for the Study of Planet Earth, Climate Assessment for the Southwest (CLIMAS), University of Arizona, September, 2007.

of the planning area, near the borders of Nevada and Utah, exhibits a stronger late winter peak, whereas the eastern and southern part of the area shows a stronger summer peak.

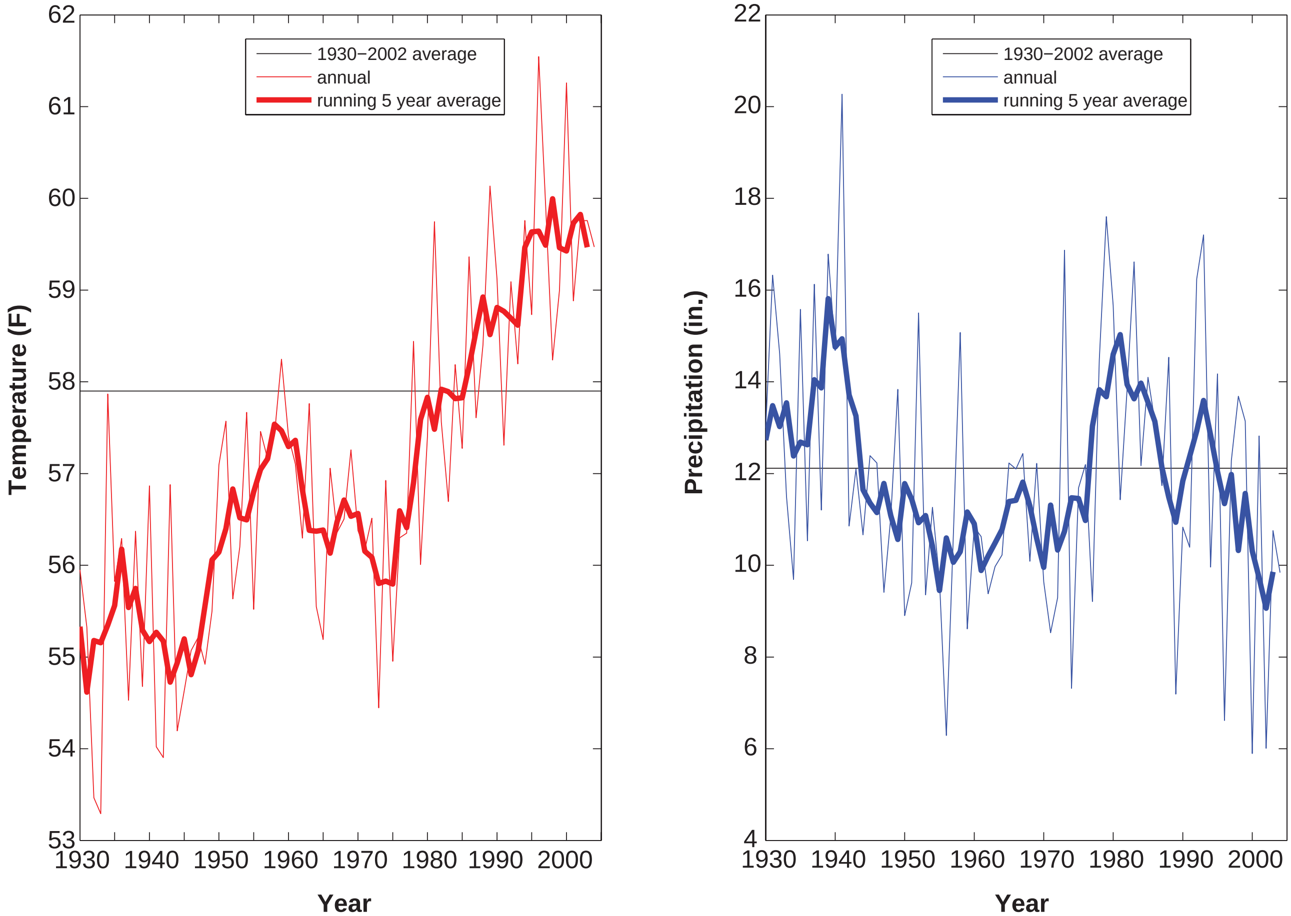
Figure 6.0-6 Average monthly precipitation and temperature from 1930-2002



Data are from the Western Regional Climate Center. Figure author: Gregg Garfin, CLIMAS

Frontal storm systems moving west-to-east, guided by the jet stream, deliver the area's winter and spring precipitation. Summer monsoon thunderstorms arrive later in this part of the state than elsewhere, and August is clearly the peak month, on average, for summer precipitation. However, year-to-year summer precipitation variability is pronounced, with some years showing July peaks. The area shows a strong response to the El Niño-Southern Oscillation, with El Niño winters registering wet conditions 52% of the time and dry conditions less than 30% of the time; La Niña winters are dry 54% of the time and wet only 21% of the time.

Figure 6.0-7 Average annual temperature and total annual precipitation for the Western Plateau Planning Area from 1930-2002

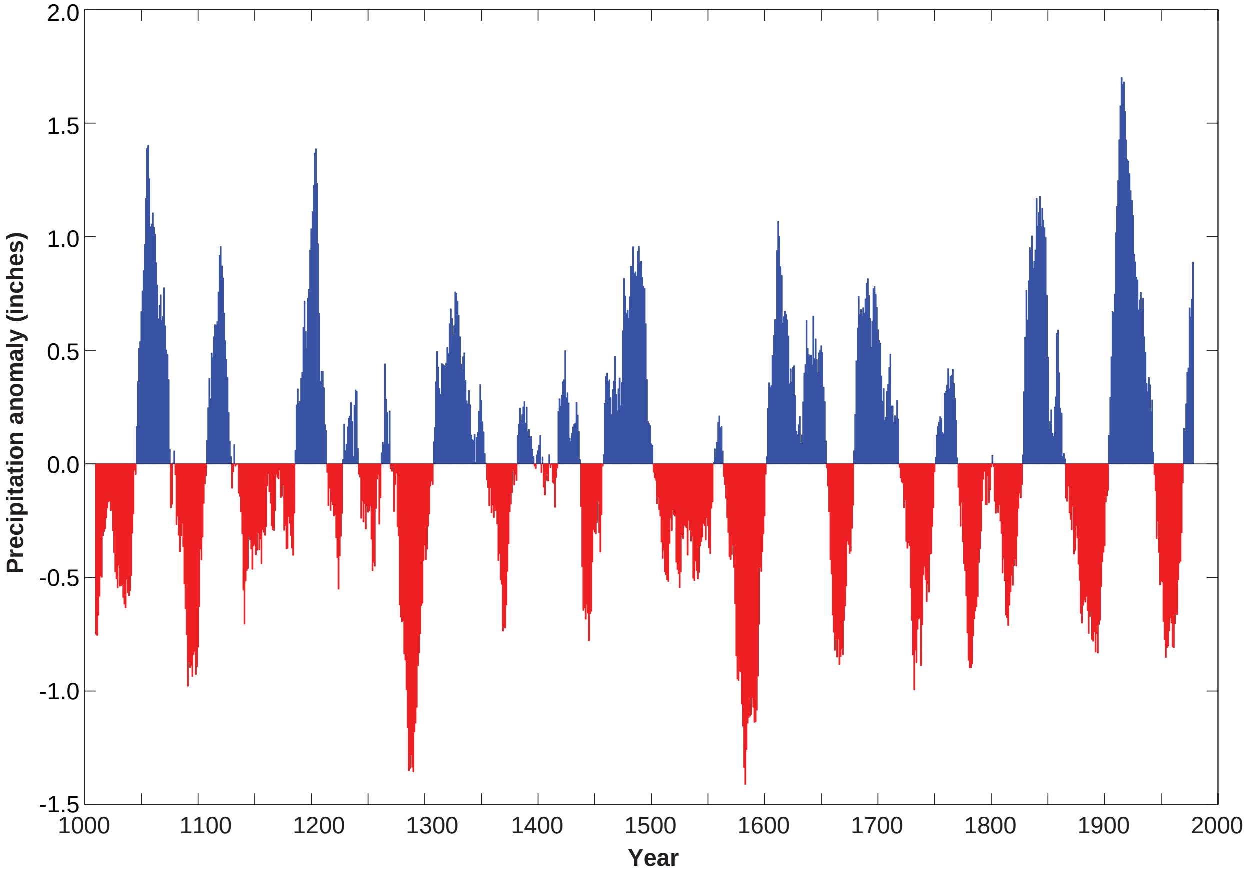


Horizontal lines are average temperature (57.9 °F) and precipitation (12.1 inches), respectively. Light lines are yearly values and highlighted lines are 5-year moving average values. Data are from the Western Regional Climate Center. Figure author: Gregg Garfin, CLIMAS.

Average annual temperatures in the Western Plateau Planning Area have been increasing since the 1930s, and especially rapidly since the mid-1970s (see Figure 6.0-7). The long-term trend is superimposed on decadal variability generated primarily by Pacific Ocean and atmosphere variations. Decadal variations are particularly obvious in the instrumental record of precipitation. Drought conditions are apparent for the decades of the 1940s-early 1970s and since the mid-1990s, whereas the 1930s and mid-1970s through the mid-1990s were relatively wet.

Winter precipitation records dating to 1000 A.D., estimated from tree-ring reconstructions for Arizona climate divisions, show extended periods of above and below average precipitation in every century (Figure 6.0-8). A climate division is a region within a state that is generally climatically homogeneous. Arizona has been divided into seven climate divisions. Notably dry periods in the Western Plateau Planning Area include the late 1500s, which feature the driest decade in this part of the state, and the late 1200s. The Western Plateau Planning Area was relatively wet during the late 1400s, early 1600s, and early 1900s.

Figure 6.0-8 Winter (November-April) precipitation departures from average, 1000-1988



Data are presented as a 20-year moving average to show variability on decadal time scales. Data: Fenbiao Ni, University of Arizona Laboratory of Tree-Ring Research and CLIMAS. Figure author: Gregg Garfin, CLIMAS.

6.0.4 Environmental Conditions

Environmental conditions reflect the geography, climate and cultural activities in an area and may be a critical consideration in water resource management and supply development. Discussed in this section is vegetation, riparian protection through the Arizona Water Protection Fund Program, instream flow claims, threatened and endangered species, public lands protected from development as national parks, monuments, recreation areas and wilderness areas, and managed waters.

Vegetation[3]

Information on ecoregions and biotic (vegetative) communities in the planning area are shown on Figure 6.0-9. Three of Arizona's six ecoregions are included in the planning area: the Colorado Plateau Shrublands, which covers most of the area, the Mojave Desert in the western portion, and the Arizona Mountains Forests ecoregion in the eastern section. Biotic communities range from Mohave desertscrub at lower elevations to a small area of alpine tundra above 12,000 feet on the

[3] Except as noted, information in this section is from AZGF, 2004.

San Francisco Peaks in the Coconino Plateau Basin. Much of the planning area is covered by Great Basin conifer woodland and plains grassland.

Alpine tundra communities are found only at the highest elevations on the San Francisco Peaks, generally over 12,000 feet. Because of the relatively harsh climate, only specially-adapted species can survive. Plants are commonly small and ground-hugging and include mosses, lichens and herbs. An area of the Peaks has been closed to travel to protect an endemic groundsel (*Senecio franciscanus*), a threatened species. The Peaks are the southernmost climatic alpine area in the United States. Small areas of subalpine grassland are also found on the San Francisco Peaks and on the Kaibab Plateau at elevations above 8,500 feet that receive from 30 to 45 inches of annual rainfall (Grahame and Sisk, 2002).

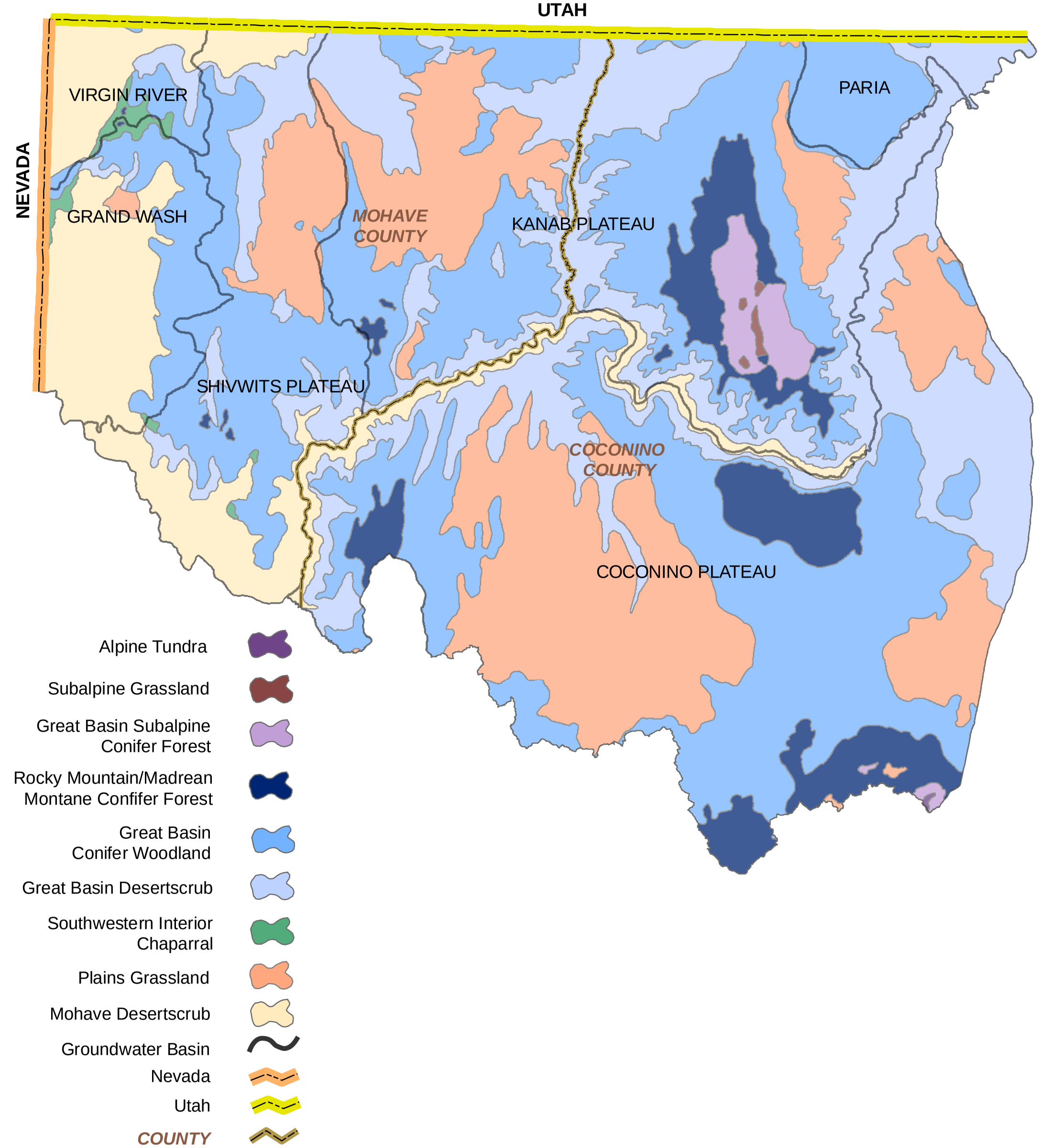
High elevation subalpine conifer forests are limited to relatively small isolated mountaintop stands on the Kaibab Plateau and the San Francisco Peaks area at elevations of 8,500 to almost 12,000 feet with annual precipitation from 30 to 40 inches a year. These forests consist of dense stands of fir, spruce and aspen trees and receive much of their annual precipitation as snow. Summer precipitation is also a substantial component of annual precipitation. Bristlecone pine stands occur at elevations around 11,000 feet on the San Francisco Peaks (Brown, 1982). Significant stands of aspen occur in places, especially in areas that have been burned. Natural fires are relatively uncommon in subalpine conifer forests with patchy crown fires occurring about every several hundred years, and surface fires occurring every 15 to 30 years (Graham and Sisk, 2002).

Rocky Mountain (Petran) and Madrean Montane conifer forests commonly occur between about 7,200 to 8,700 feet. Above 8,000 feet in areas that receive from 25 to 30 inches of annual rainfall, the forest contains a mix of conifers that may include Douglas-fir, white fir, limber pine, blue spruce, and white pine, with ponderosa pine joining the mix on warmer slopes. Aspen and Gambel oak are prominent in these forests following disturbances. Below 8,000 feet in areas that receive about 18 to 26 inches of annual precipitation, the mix of species gives way to almost pure stands of ponderosa pine, particularly on the Kaibab Plateau and at the south rim of the Grand Canyon. About half of the precipitation occurs during the growing season, which permits forests to exist on less than 25 inches of annual rainfall, making them some of the driest forests in North America (Brown, 1982).

Several years of drought combined with high tree densities resulted in the largest outbreak of pine bark beetle populations ever recorded in Arizona during 2002 – 2004. While drought conditions improved in 2004 and 2005, by 2006, Ponderosa pine mortality due to Ips beetles increased, with 6,850 acres infested on the Kaibab National Forest. Other beetle species have also attacked trees on the Kaibab Plateau and on the San Francisco Peaks (USDA, 2006). Based on aerial surveys conducted in 2004 by the U.S. Forest Service, substantial bark beetle-caused ponderosa pine mortality occurred in a swath of forest stretching northeast from Williams and on forest lands south of the South Rim of the Grand Canyon.

Great Basin Conifer (piñon-juniper) woodlands cover large areas below the ponderosa pine forest at elevations between about 5,000 and 7,500 feet that receive about 10 to 20 inches of annual precipitation. Extensive stands exist throughout the planning area as shown on Figure 6.0-9. Piñon

Figure 6.0-9
Western Plateau Planning Area
Biotic Communities and Ecoregions



Biotic Communities Source: AGFD, 1993
Ecoregions Source: World Wildlife Fund, 2004

pine dominates at higher elevation while junipers are the dominant species at lower and drier areas that may include open grasslands. Bark beetle infestations have killed large areas of piñon pine southeast of Valle and smaller areas south of the South Rim in the Coconino Plateau Basin.

Plains grasslands, primarily composed of mixed or short-grass communities, are widespread in the planning area at elevations above about 4,000 feet that receive between 11 and 18 inches of annual precipitation. These areas are located primarily in the Coconino Plateau, Kanab Plateau and Shivwits Plateau basins. On the Arizona Strip, Great Plains grassland, which is drier and receives a larger percentage of annual rainfall in the winter and spring, transitions with plains grasslands (Brown, 1982). Native bunchgrasses have been largely replaced by Eurasian annual species such as cheatgrass due to grazing and fire-suppression practices (Grahame and Sisk, 2002).

Interior chaparral occupies mid-elevation foothill, mountain slopes and canyons in the Virgin Mountains in the Virgin River and Grand Wash basins, and in several isolated locations in the southern part of the Shivwits Plateau Basin. It is found in areas between about 3,500 and 6,000 feet in elevation that receive 15 to 25 inches of annual precipitation (Brown, 1982). Chaparral consists of dense shrubs that grow around the same height with occasional taller shrubs or small trees. Typical shrubby species are mountain mahogany, shrub live oak, and manzanita. Chaparral plants are well adapted to drought conditions.

Great Basin Desertscrub occurs in northern Arizona mostly at elevations of 4,000 to 6,500 feet where an average of about 7 to 12 inches of rainfall occurs. This vegetative community is dominated by multi-branched, aromatic shrubs with evergreen leaves, primarily sagebrush, blackbrush and shadscale. Great Basin Desertscrub is found in all basins in the Western Plateau Planning Area except the Paria Basin. In addition to shrubs, vegetation consists primarily of grasses. Grazing has heavily impacted native grasses in this community, which have been replaced by exotic species including cheatgrass. Cheatgrass is highly flammable, and where it is a significant component of sagebrush stands, the incidence of fire is greatly increased (Brown, 1982).

Mohave Desertscrub covers a transitional zone between the higher and cooler Great Basin desert and the lower, hotter Sonoran desert. It is found along the Colorado River and in the western part of the planning area at elevations below about 3,500 feet. While many of the same plants found in the other deserts occur here, some are found only in the Mohave Desert such as the Joshua tree. The Mohave Desert is rich in endemic ephemeral plants, most of which are winter annuals (Brown, 1982).

There are reaches of riparian vegetation along the few watercourses in the planning area including Kanab Creek, the Paria River and the Colorado River. However, these areas are not well mapped. Tamarisk and strand communities exist along the Virgin River. Dixon and Katzer (2000) estimated that nearly 10,000 acre-feet of water is used by phreatophytes along the Virgin River from the Littlefield gage to the state line.

Arizona Water Protection Fund Programs

The objective of the Arizona Water Protection Fund Program (AWPF) program is to provide funds for protection and restoration of Arizona's rivers and streams and associated riparian habitats. Eight restoration projects in the Western Plateau Planning Area have been funded by the AWPF through 2005. Five projects were funded in the Coconino Plateau Basin and primarily involve research. Three Kanab Plateau Basin projects funded research, exotic species control, revegetation and watershed enhancement. A list of projects and project types funded in the Western Plateau Planning Area through 2005 is found in Appendix A of this volume. A description of the program, a complete listing of all projects funded, and a reference map is found in Appendix C of Volume 1.

Instream Flow Claims

An instream flow water right is a non-diversionary appropriation of surface water for recreation and wildlife use. Seven applications for instream flow claims were filed by the Bureau of Land Management in the Virgin River Basin. Six applications have been filed on reaches of the Virgin River and one has been filed on a reach of Beaver Dam Wash. All applications are currently pending. Applications are listed in Table 6.0-1 and shown on Figure 6.0-10.

Table 6.0-1 Instream flow claims in the Western Plateau Planning Area

Map Key	Stream	Applicant	Application No.	Permit No.	Certificate No.	Filing Date
1	Beaver Dam Wash	BLM (Arizona Strip)	33-94843.0	Pending	Pending	8/24/1989
2	Virgin River	BLM (Arizona Strip)	33-94819.0	Pending	Pending	6/1/1989
3	Virgin River	BLM (Arizona Strip)	33-94865.0	Pending	Pending	10/20/1989
4	Virgin River	BLM (Arizona Strip)	33-96159.0	Pending	Pending	12/23/1991
5	Virgin River	BLM (Arizona Strip)	33-94866.0	Pending	Pending	10/20/1989
6	Virgin River	BLM (Arizona Strip)	33-96134.0	Pending	Pending	10/30/1991
7	Virgin River	BLM (Arizona Strip)	33-96133.0	Pending	Pending	10/30/1991

ADWR 2005a

Threatened and Endangered Species

A number of listed threatened and endangered species may be present in the Western Plateau Planning Area. Those listed by the U.S. Fish and Wildlife Service (USFWS) as of May 2006 are shown in Table 6.0-2.[4] Presence of a listed species may be a critical consideration in water resource management and supply development in a particular area. The USFWS should be contacted for details regarding the Endangered Species Act (ESA), designated critical habitat and current listings.

[4] An "endangered species" is defined by the USFWS as "an animal or plant species in danger of extinction throughout all or a significant portion of its range," while a "threatened species" is "an animal or plant species likely to become endangered within the foreseeable future throughout all or a significant portion of its range."

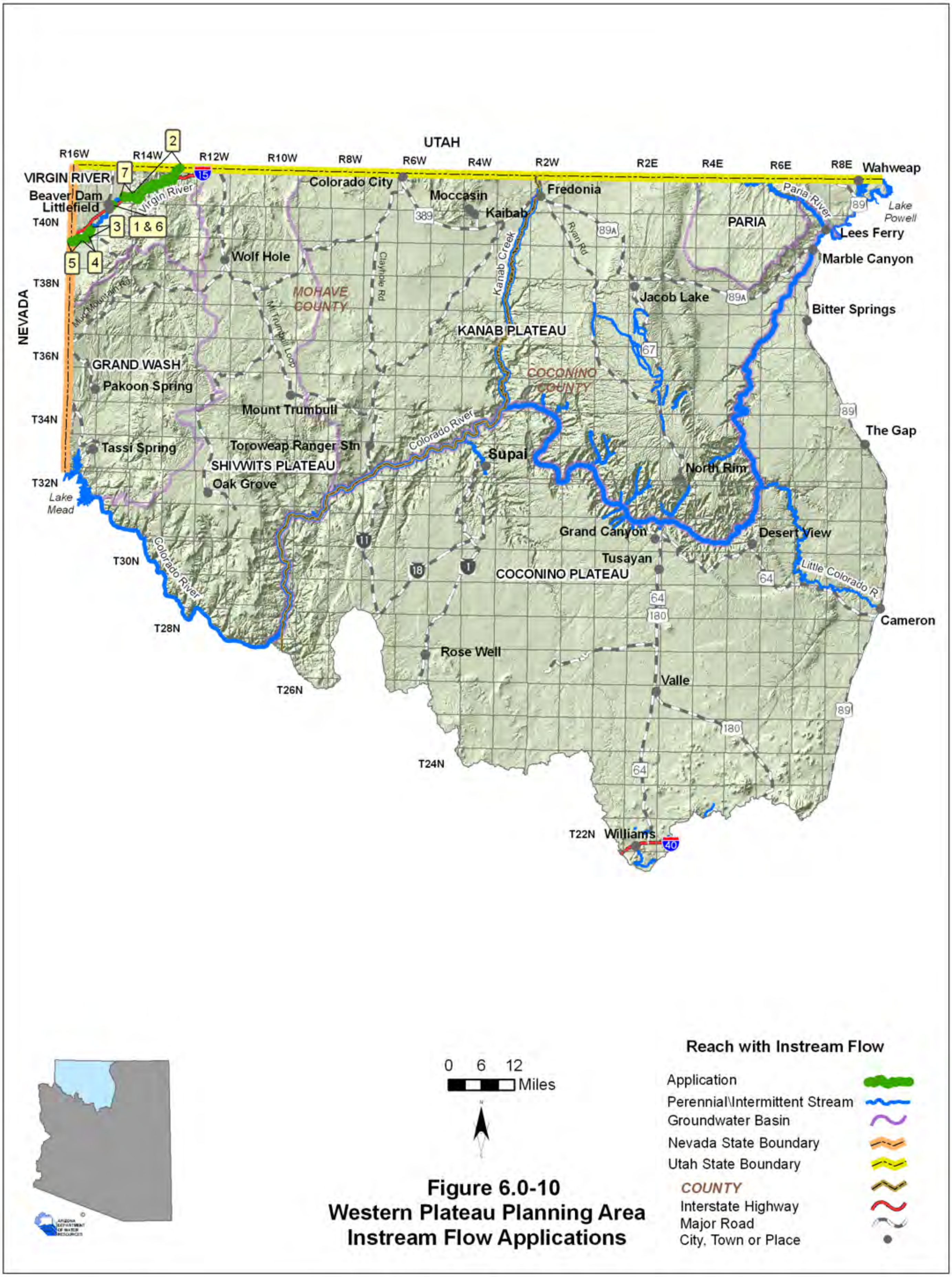


Figure 6.0-10
Western Plateau Planning Area
Instream Flow Applications

A unique example of endangered species management in the planning area is that of the California condor. Considered one of the most endangered birds in the world, condors were placed on the federal endangered species list in 1967 and in 1987, with only 22 individuals known to exist, a controversial decision was made to bring all remaining condors into captivity in order to conduct a captive breeding program with the goal of reintroducing the species to the wild. Beginning in 1996, six to ten birds have been released each year from the Vermilion Cliffs in the Paria Basin. There are now over 60 condors in Arizona. In Arizona, reintroduction of the condor was conducted under a special provision of the ESA that allows for the designation of a nonessential experimental population. Under this designation, endangered species protections are relaxed, providing greater flexibility for management of a reintroduction program (AZGF, 2006).

National Parks, Monuments, Recreation Areas and Wilderness Areas

The Western Plateau Planning Area has the greatest number of federally protected areas as parks, monuments, recreation areas and wilderness areas of any planning area. It contains almost all of Grand Canyon National Park, three national monuments and small parts of two national recreation areas. In total there are 2.68 million acres of protected federal lands in the planning area, accounting for 31% of the land area. The Grand Canyon and Grand Canyon-Parashant National Monument make up most of the total with more than 2 million combined acres.

Ten wilderness areas are entirely within the planning area as well as part of another. Wilderness Areas are designated under the 1964 Wilderness Act to preserve and protect the designated area in its natural condition. Designated areas, their size, basin location and a brief description of the area are listed in Table 6.0-3. Five wilderness areas are within the boundaries of national monuments.

Grand Canyon National Park, a World Heritage Site, encompasses 1,218,375 acres. It was given Federal protection in 1893 as a Forest Reserve and later as a National Monument, and achieved National Park status in 1919. It receives almost five million visitors each year. Water for both the North and South Rims of the Park come from Roaring Springs, located 3,000 feet below the North Rim, and transported via pipeline to both rims (see Section 6.0.7) (USBOR, 2002). Park lands exist in every groundwater basin except the Virgin River and Paria basins, stretching from the confluence of the Little Colorado and Colorado Rivers west to Lake Mead (see landownership maps in the basin sections).

The Grand Canyon is of great geologic significance, with a record of three of the four eras of geological time, a rich and diverse fossil record, a huge variety of geologic features and rock types, and numerous caves containing extensive geological, paleontological, archeological and biological resources. Incised by the Colorado River, the Canyon is considered one of the finest examples of arid-land erosion in the world, averaging 4,000 feet deep for its entire 277 miles (NPS , 2005).

The Park contains a diversity of biotic communities ranging from Mohave Desertscrub to Subalpine Conifer Forest. It serves as an ecological refuge, with relatively undisturbed remnants of dwindling ecosystems, including desert riparian communities. It is home to numerous rare, endemic, and federally protected plant and animal species (NPS, 2007).

Table 6.0-2 Listed threatened and endangered species in the Western Plateau Planning Area

Common Name	Threatened	Endangered	Elevation/Habitat
Brady Pincushion Cactus		X	3,400-5,200 ft/Gravelly alluvium with sparse vegetation on gently sloping benches and terraces
Bald Eagle	X		Varies/Large trees or cliffs near water
California Brown Pelican		X	Varies/Lakes and rivers
California Condor		X	2,000-6,500 ft/Steep terrain with rock outcroppings, cliffs and caves
Desert Tortoise (Mohave Population)	X		1,000-4,000 ft./Sandy loam to rocky soils in valleys, bajadas and hills
Holmgren Milk-Vetch		X	2,480-2,999 ft./Skirt edges of hill and plateau formations slightly above or at the edge of drainage areas
Humpback Chub		X	1,530-4,400 ft/Turbulent, high gradient, canyon-bound reaches of large rivers
Jones' Cycladenia	X		4,000 to 6,800 ft/ Mixed desert shrub and scattered piñon-juniper communities
Kanab Amber Snail		X	3,200 ft./Marshes watered by springs and seeps at the base of sandstone cliffs or limestone
Mexican Spotted Owl	X		4,100-9,000 ft./Canyons and dense forests with multi-layered foliage structure
Razorback Sucker		X	<6,000 ft./Riverine and lacustrine areas, not in fast moving water
San Francisco Peaks Groundsel	X		>10,900 ft./Alpine tundra
Sentry Milk-Vetch		X	7,000-7,960 ft/Uppermost layer of Kaibab limestone that is weathered in small, shallow pockets and networks of small cracks
Siler Pincushion	X		2,800-5,800 ft/Low red or gray gypsiferous badlands
Southwestern Willow Flycatcher		X	<8,500 ft./cottonwood-willow and tamarisk along rivers and streams
Virgin River Chub		X	1,540-2,360 ft/Swift but not turbulent areas of the Virgin River
Welsh's Milkweed	X		4,700-6,250 ft/Open, sparsely vegetated sand dunes or sagebrush, juniper, pine and oak communities
Woundfin		X	1,900-10,000 ft./Swift parts of silty streams
Yuma Clapper Rail		X	<4,500 ft./Fresh water and brackish marshes

Source: USFWS 2006, USDOI 2007

Table 6.0-3 Wilderness areas in the Western Plateau Planning Area

Wilderness Area	Acres	Basin	Description
Beaver Dam Mountain	19,600	Virgin River	Rugged mountains, alluvial plains and several miles of the Virgin River
Cottonwood Point	6,860	Kanab Plateau	Navajo sandstone cliffs, canyons and pinnacles, willow and cottonwoods in wetter canyons
Grand Wash Cliffs*	37,030	Grand Wash	Marks transition zone between Colorado Plateau and Basin and Range provinces and contains many canyons
Kachina Peaks	18,615	Coconino Plateau (part)	Mt. Humphrey's and only arctic-alpine vegetation in the state
Kanab Creek	68,340	Kanab Plateau	Kanab Creek and a maze of water and wind carved fins, knobs and potholes
Kendrick Mountain	6,510	Coconino Plateau	Remnant of San Francisco Mountain volcanic field
Mt. Logan*	87,900	Grand Wash	Basalt ledges, cinder cones and large eroded amphitheater
Mt. Trumbull*	7,880	Kanab Plateau	Large basalt-capped mesa
Paiute*	87,900	Grand Wash, Virgin River	Virgin Mountains and canyons
Paria Canyon-Vermillion Cliffs*	112,500	Kanab Plateau, Paria (part)	Paria Canyon and Vermillion Cliffs, red rock amphitheaters, sandstone arches, towering walls and hanging gardens
Saddle Mountain	40,610	Kanab Plateau	Nankoweap rim, narrow drainage bottoms and steep scarp slopes.

Source: BLM 2006, USFS 2007
*Wilderness areas are within the boundaries of a National Monument

Construction and operation of Glen Canyon Dam has significantly altered Colorado River flows and the sediment, wildlife and habitat along the river in Grand Canyon National Park. A number of studies and actions have been taken and are underway to manage releases from the dam to protect the Park's resources and to mitigate the impact of dam operations. (See "Managed Waters" below).

The Grand Canyon-Parashant National Monument was created by Presidential Proclamation in January 2000. At 1.05 million acres, it is described in the Proclamation as a geological treasure and as a "vast, biologically diverse, impressive landscape…" The physical remoteness of the monument has helped preserve important biological and archeological resources. The monument encompasses the lower portion of the Shivwits Plateau Basin, considered an important watershed for the Colorado River and the Grand Canyon, almost all of Grand Wash Basin and a small area north of Toroweap in the Kanab Plateau Basin (USDOI, 2007). The Monument is jointly administered by the National Park Service (NPS), (211,100 acres) and the Bureau of Land Management (BLM), (808,727 acres).

In November 2000, President Clinton also established the Vermilion Cliffs National Monument by proclamation. Encompassing 294,000 acres, the entire monument is within Arizona. Most of the Paria Plateau Basin and adjoining lands in the Kanab Plateau Basin are within the monument boundaries. The monument was established to protect geologic features including the 2,500-foot deep Paria Canyon, the Paria Plateau, the spectacular cross-bedded sandstones at Coyote Buttes and the 3,000-foot Vermilion Cliffs escarpment, the Arizona release site of the endangered California condor.

In March 2007, the Arizona Strip Proposed Plan/Final Environmental Impact Statement (FEIS) was released. The Proposed Plan/FEIS serves multiple functions. It is a revised Resource Management Plan for the Arizona Strip Field Office, a new management plan for the Vermilion Cliffs National Monument and a new management plan for the Grand Canyon-Parashant National Monument. It is also a Proposed General Management Plan/Final EIS for the NPS portion of the Grand Canyon-Parashant National Monument, since that monument is jointly administered by the BLM and NPS.

The Proposed Plan/FEIS describes and analyzes five alternatives for managing over 3.3 million acres of lands. Major issues include management of access, management of areas having wilderness characteristics, protection of natural and cultural resources, management of livestock grazing, and recreation. There will be three final management plans that result from this effort with four records of decision signed by the BLM and NPS later in 2007 (BLM, 2007). Over 8,500 comments were received during the public scoping process conducted in preparation of the draft EIS. Most comments were related to concerns about vehicular access and wilderness and resource protection. Both monuments are withdrawn from mineral entry. Grazing is allowed with adjustments to meet management objectives and adjustments will be made to routes as necessary. Further evaluation of routes in the entire area will continue for several years (USDOI, 2007).

Pipe Spring National Monument, established in 1923, is located in the Kanab Plateau Basin south of Kaibab and Moccasin. It is a cultural park occupied by several cultures over a period of about 2,000 years due to the occurrence of springs, which have supported farming and ranching activities. There are four springs within the monument boundaries: West Cabin, Main, Spring Room and Tunnel. Main Spring and Spring Room have man-made discharge points constructed by Mormon pioneers and are believed to represent the flow of the original natural spring known as Pipe Spring. Since 1976, NPS staff has measured spring discharge on a monthly basis due to concerns about declines in discharge rates (Truini, et al., 2004).

About 3% of the 1.2 million-acre Glen Canyon National Recreation Area is located in the northeastern corner of the Paria Basin. The Recreation area was created by Congress in 1972 to provide for recreational use of Lake Powell and adjacent lands and to preserve scenic, scientific, and historic features. It surrounds and includes Lake Powell from Lees Ferry to the Orange Cliffs in Utah. The principal recreation area development within the planning area is Wahweap, which includes a marina, campground and visitor center. Fluctuations in the lake level affect recreational activities in the area. Since designation of the Grand Canyon-Parashant N.M., the only remaining portion of the Lake Mead National Recreation Area in the planning area is Lake Mead itself.

Managed Waters

The Colorado River is among the most managed rivers in the United States. The river is impounded behind Glen Canyon Dam, which is managed for both electrical generation purposes and to store water to meet flow obligations at Lees Ferry under the terms of the 1922 Colorado River Compact. As a result, the river's flow and the ecosystem it supports have been fundamentally altered. The Colorado River was a warm, sediment-laden river that historically carried a daily average of 275,000 tons of sediment through the Grand Canyon. Water temperature varied through the year and large spring floods and varying flow patterns deposited sediment along the riverbanks and provided habitat, including calm spawning pools, for a number of native fish species. Operation of the dam for electrical generation requires large water releases during historically low flow seasons with daily and weekly fluctuations. The flow regime is governed by the Record of Decision for the Glen Canyon Dam EIS and the Glen Canyon Operating Criteria (see section 6.0.2). The water released from the bottom of the reservoir is now consistently cold year round and considerably less sediment is now carried downstream, impacting beach building along the riverbank. Vegetative communities, wildlife and native fish have been affected by the modified river flow (Tellman, et al. 1997). The Colorado pike minnow and bonytail chub no longer occur in the Grand Canyon, and the humpback chub and razorback sucker are listed as endangered species.

Beginning in 1982, the Bureau of Reclamation initiated the multi-agency interdisciplinary Glen Canyon Dam Environmental Studies to evaluate the impact of Glen Canyon Dam and how its operation could be modified to address wildlife and recreational values downstream of the dam. In 1989, work on an EIS began to consider options for the operation of the dam. The EIS was completed in 1995 and findings indicated that there were a number of uncertainties regarding the downstream impact of water releases from the Dam. While the EIS was being developed, Congress passed the Grand Canyon Protection Act (Act) of 1992 (Public Law 102-575), which required operation of the dam in a manner that would protect and mitigate adverse impacts to Grand Canyon National Park and Glen Canyon National Recreation Area. In compliance with this Act, the EIS proposed an adaptive management process to monitor and assess the effects of dam operations on downstream resources. (USBOR, 2007c)

In 1997, then Secretary of Interior (Secretary), Bruce Babbitt, established an Adaptive Management Program (AMP) to "provide an organization and process for cooperative integration of dam operations, downstream resource protection and management, and monitoring and research information…". Critical to the program is the Glen Canyon Adaptive Management Work Group (AMWG), a federal advisory committee. The AMWG incorporates stakeholders into the decision-making process and makes recommendations to the Secretary on how to protect resources. The group completed a draft strategic plan in 2001 and current focus includes recovery of humpback chub, management of sediment resources and experimental releases of water from Glen Canyon Dam (USBOR, 2007c). Before release of the EIS, the Secretary authorized an artificial flood in the Grand Canyon that would mimic historic spring flows, in order to help build beaches and habitat. The flood temporarily restored beaches and improved backwater habitat, but pre-flood conditions quickly returned.

As part of the AMP effort, the Bureau of Reclamation completed a scoping report in March 2007 for the Glen Canyon Dam Long-term Experimental Plan EIS. The proposed plan would implement a long-term program in the Colorado River below the dam that could potentially involve dam operations, modifications to the dam's intake structures and other management actions such as removal of non-native fish (USBOR,2007c).

Another activity that will impact how releases are managed from Glen Canyon Dam is the development of guidelines for the operation of the reservoir under shortage conditions. Each year, the Secretary is required to declare whether the Colorado River water supply is in a normal, surplus or shortage condition for the Lower Basin States (Arizona, California, Nevada). Regulations and operations criteria have never been established for shortage conditions. Following multiple years of drought and decreasing water supplies in storage, in May 2005 the Secretary directed that the Bureau of Reclamation develop guidelines for the operations of Lake Powell and Lake Mead under low reservoir conditions. These guidelines will provide more predictability regarding expected annual water deliveries. An EIS is being completed for this effort, expected to be finalized in September 2007 (USBOR, 2007d).

The preferred alternative under shortage conditions includes: adoption of guidelines to identify under what circumstances the Secretary would reduce the annual amount of water available to the Lower Basin States from Lake Mead below 7.5 maf/year; adoption of guidelines for the coordinated operation of Lake Mead and Lake Powell to improve operations under low reservoir conditions; and adoption of guidelines to allow storage and delivery of conserved water in Lake Mead to increase the flexibility of meeting water needs under drought and low storage conditions. The final EIS will include a determination of the environmental impact of the preferred alternative (USBOR, 2007e).

Unlike the Colorado River, the Virgin River flows uninterrupted from its headwaters above Zion National Park to Lake Mead. Water is diverted from the Virgin River for municipal and agricultural needs in Utah and for agricultural use in Arizona. This river, particularly its upper reaches, is recognized for its recreational and scenic values but is not federally managed or protected.

6.0.5 Population

The Western Plateau Planning Area is the most sparsely populated planning area in the state although there are some rapidly growing areas. Census data for 2000 show about 17,200 residents in the planning area. Arizona Department of Economic Security (DES) population projections suggest that the planning area population will more than double by 2050, to about 35,000 residents. Historic, current and projected basin population is shown in the cultural water demand tables for each basin in Sections 6.1-6.6.

The most populous basin is the Coconino Plateau with about 9,500 residents in 2000. The Shivwits Plateau and Grand Wash basins have very low populations with 12 and 15 residents, respectively. The 2000 Census populations for each basin and Indian reservation, listed from highest to lowest, are shown in Table 6.0-4.

Table 6.0-4 2000 Census population of basins and Indian reservations in the Western Plateau Planning Area

Basin/Reservation	2000 Census Population
Coconino Plateau	9,164
Havasupai	*650*
Navajo	*3,068*
Kanab Plateau	5,930
Kaibab-Paiute	*196*
Virgin River	1,532
Paria	555
Grand Wash	15
Shivwits Plateau	12

Shown in Table 6.0-5 are incorporated and unincorporated communities in the planning area with 2000 Census populations greater than 500 and growth rates for two time periods. Communities are listed from highest to lowest population in 2000. The planning area population grew by 25% between 1990 and 2000. There are only two incorporated communities within the planning area, Colorado City and Williams. Rapid growth is occurring in several areas including Beaver Dam/ Littlefield, Colorado City, Valle and recently, Williams. The unincorporated areas of Beaver Dam/ Littlefield and nearby Scenic, Arizona, are growing rapidly in large part due to growth in Mesquite, Nevada, the state's fastest growing community. Mesquite experienced an annual growth rate of almost 9% between 2000 and 2005, fueled by development of retirement communities and its growing popularity as a resort destination.

Population Growth and Water Use

Arizona has limited mechanisms to address the connections between land use, population growth and water supply. A legislative attempt to link growth and water management planning is the Growing Smarter Plus Act of 2000 (Act) which requires that counties with a population greater than 125,000 (2000 Census) include planning for water resources in their comprehensive plans. Of the two counties in the planning area, only Mohave County fit the size criteria in 2000. The Mohave County water resources element will develop a water budget for each of the groundwater basins in the county and will prioritize this effort based on growth potential, water availability, number of wells and other factors (Freilich, Leitner & Carlisle, 2005). However, the County's key water issues are related primarily to that part of the County south of the Colorado River.

The Act also requires that twenty-three communities outside AMAs include a water resources element in their general plans. In the Western Plateau Planning Area this requirement applies only to Colorado City. Plans must consider water demand and water resource availability in conjunction with growth, land use and infrastructure.

Beginning in 2007, all community water systems in the state are required to submit Annual Water Use Reports and System Water Plans to the Department. The reports and plans are intended to reduce community water systems' vulnerability to drought, and to promote water resource planning to ensure that water providers are prepared to respond to water shortage conditions. In addition, the information will allow the State to provide regional planning assistance to help communities prepare for, mitigate and respond to drought. An Annual Water Use Report will be submitted each year by the systems, beginning June 1, 2007, and include information on water pumped or diverted, water received, water delivered to customers, and effluent used or received. The System Water Plan will be updated and submitted every five years and will consist of three components, a Water Supply Plan, a Drought Preparedness Plan and a Water Conservation Plan. Systems serving populations greater than 1,850 were required to submit plans by January 1, 2007. Systems that serve populations less than 1,850 are required to submit plans by January 1, 2008. Plans have been submitted by the large systems of City of Williams and Colorado City, and by the small systems of Grand Canyon National Park and HydroResources-Tusayan. These plans were used to prepare this document.

Table 6.0-5 Communities in the Western Plateau Planning Area with a 2000 Census population greater than 500

Communities	Basin	1990 Census Pop.	2000 Census Pop.	Percent Change 1990-2000	2005 Pop. Estimate	Percent Change 2000-2005	Projected 2050 Pop.
Colorado City*	Kanab Plateau	2,426	3,334	37%	4,080	22%	8,887
City of Williams*	Coconino Plateau	2,532	2,842	12%	3,145	11%	4,587
Grand Canyon Village	Coconino Plateau	1,499	1,460	-3%	NA	NA	2,693
Town of Cameron	Coconino Plateau	1,011	1,231	22%	NA	NA	4,157
Beaver Dam/Littlefield	Virgin River	762	1,053	38%	NA	NA	NA
Town of Fredonia	Kanab Plateau	1,207	1,036	-14%	1,110	7%	1,462
Town of Tusayan	Coconino Plateau	NA	562	NA	NA	NA	774
Town of Valle	Coconino Plateau	123	534	334%	NA	NA	1,010
Total >500		9,560	12,052	21%	NA	NA	NA
Other		3,382	5,156	34%	NA	NA	NA
Total		**12,942**	**17,208**	25%	NA	NA	**35,266**

Source: DES 2005: www.workforce.az.gov, U.S. Census Bureau 2006, BOR 2006
Notes: 2005 population estimates not available for unincorporated communities
NA = not available
* = incorporated communities

The Department's Water Adequacy Program also relates water supply and demand to growth to some extent, but does not control growth. Developers of subdivisions outside of AMAs are required to obtain a determination of whether there is sufficient water of adequate quality available for 100 years. If the supply is inadequate, lots may still be sold, but the condition of the water supply must be disclosed in promotional materials and in sales documents. Legislation adopted in June 2007 (SB 1575) authorizes a county board of supervisors to adopt a provision, by unanimous vote, which requires a new subdivision to have an adequate water supply in order for the subdivision to be approved by the platting authority. If adopted, cities and towns within the county may not approve a subdivision unless it has an adequate water supply. If the county does not adopt the provision, the legislation allows a city or town to adopt a local adequacy ordinance that requires a demonstration of adequacy before the final plat can be approved.

Subdivision adequacy determinations (Water Adequacy Reports), including the reason for the inadequate determination, are provided in the basin sections of this volume and are summarized for each basin in Table 6.0-6. As shown, there were a limited number of subdivisions with a water adequacy determination in the planning area. All subdivisions were found to have an inadequate water supply in the Coconino Plateau Basin while all subdivisions were found to have an adequate supply in the Paria Basin. Since 2005, additional applications have been filed in the Virgin River Basin. The largest is a pending application for Beaver Dam Ranch, a 1,840-acre development with a projected demand of 5,300 acre-feet per year at build out.

Table 6.0-6 Water Adequacy Determinations in the Western Plateau Planning Area as of 2005

Basin	Number of Subdivisions	Number of Lots[1]	Lots w/ Adequate Determ.	Lots w/ Inadequate Determ.	Approx. Percent of Lots w/ Percent Inadequate Determ.
Coconino Plateau	27	>1194	0	>1194	100%
Grand Wash	none	none	none	none	none
Kanab Plateau	9	360	201	159	44%
Paria	6	991	991	0	0%
Shivwits Plateau	none	none	none	none	none
Virgin River	10	>627	>601	26	4%

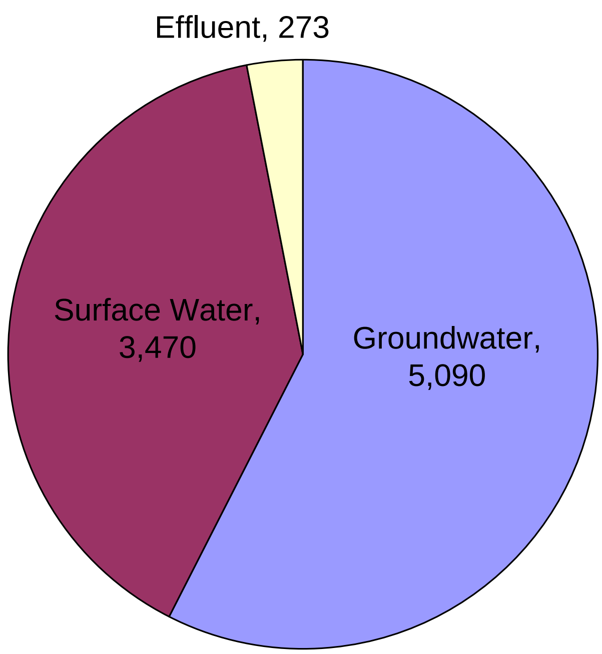
Source: ADWR 2006
Notes:
[1] Data on number of lots are missing for some subdivisions; actual number is larger

No water providers in the planning area are designated as having an adequate water supply for their entire service area. A service area designation exempts subdivisions from demonstrating water adequacy if served by the provider.

6.0.6 Water Supply

Water supplies in the Western Plateau Planning Area include groundwater, surface water and effluent. As shown on Figure 6.0-11, groundwater is the primary water supply, accounting for about 58% of the demand. Surface water is used for agricultural irrigation in the Virgin River and Kanab Plateau basins and for municipal use in the Coconino Plateau and Kanab Plateau basins. It is estimated that about 39% of the total water demand is met with surface water. Effluent is utilized for golf course irrigation and for landscape irrigation in the Coconino Plateau Basin, contributing 3% of the planning area's water supply. For purposes of the Atlas, water diverted from a watercourse or spring is considered surface water and if it is pumped from wells, it is accounted for as groundwater. This is reflected in the cultural water demand tables in each basin section.

Figure 6.0-11 Water supplies utilized in the Western Plateau Planning Area in acre-feet (average annual use 2001-2003)



Surface Water

About 3,500 acre-feet per year of surface water diverted from streams or springs is used on average in the planning area. Surface water is used primarily for agricultural irrigation but also as a municipal and industrial water supply.

Municipal and Industrial Supply
Surface water from Roaring Springs, located 3,000 feet below the North Rim of the Grand Canyon, is the primary water supply for both the North and South Rims. Spring water is pumped to the

North Rim from the Roaring Springs pump station and delivered via the trans-canyon pipeline. The trans-canyon pipeline delivers water by gravity flow to Indian Gardens, located below the South Rim, where it is pumped from the Indian Garden pump station through a directional bore hole to water storage tanks on the South Rim. A small portion of the water flowing to Indian Gardens is diverted from the pipeline to Phantom Ranch and Cottonwood Campground. The pipeline has experienced failures an average of 10 to 12 times a year due to washouts during high flow events and bends in the pipeline. For this reason, the Park is studying alternatives to provide reliable, long-term water supplies. Potential alternatives that have been identified include construction of wellfields, diversion of Colorado River Water to the South Rim, trucking in water, construction of an infiltration gallery and pumping plant on Bright Angel Creek to supply the South Rim and Phantom Ranch, and other alternatives (USBOR, 2002). There are concerns regarding use of current and future supplies and potential impacts on seeps and springs in the Grand Canyon. Several Arizona Water Protection Fund Projects have funded studies to help research these impacts.

In the Coconino Plateau Basin, the City of Williams historically relied on surface water stored in five small reservoirs with a combined storage capacity of 893 million gallons (2,740 acre-feet). The reservoirs, constructed between 1892 and 1952, collect inflow from snowmelt. Evaporation and seepage from the reservoirs is substantial, with losses greater than the city's annual demand. Two dry years in a row can result in significant stress to the supply system. When surface water supplies were seriously impacted in 1996 the City began a well drilling program to supplement its surface water supplies during periods of shortage (Pinkham and Davis, 2002).

Havasu Creek, which flows from springs emanating from the Redwall-Muav Formations, is a water supply for the Havasupai Tribe at Supai. Surface water is used as both a municipal and agricultural supply on the reservation.

In the Kanab Plateau Basin, about half of Fredonia's municipal water supply is surface water from springs, the rest is water delivered from Utah. Jacob Lake Lodge uses about seven acre-feet of spring water a year from Warm Spring. Surface water from springs is also a supply for Twin City Water (Colorado City) and Badger Creek Water in the small community of Vermilion Cliffs. Marble Canyon Co. has a Colorado River contract for 70 acre-feet per year.

The springs at Pipe Springs National Monument have historically been used for domestic, ranching and farming purposes. A pipeline from Tunnel Spring conveys water outside the monument to maintain water-use agreements with the local cattleman's association. In 1971, a well was drilled outside the monument to meet the growing needs of the monument and the Kaibab-Paiute Indian Tribe (Truini, 2004).

In the Virgin River Basin, a small amount of surface water is diverted from Beaver Dam Wash for golf course irrigation.

<u>Agricultural Supply</u>

In the Kanab Plateau Basin, between 1,400 to 1,850 acres of alfalfa, pasture and a minor amount of grain and corn were historically irrigated with surface water from Kanab Creek, diverted between the Kanab Dam and the Fredonia Dam (ADWR, 1998). It is not known precisely how many acres are currently actively irrigated but based on a cursory observation of the area in August 2007 and recent aerial photos, there appears to be far less irrigated land and surface water use now than in the past. The Arizona Strip Partnership (now inactive) identified the lack of sufficient surface water supplies for agriculture as an issue in Fredonia.

In 2000, about 1,700 acres in the Littlefield area in the Virgin River Basin were in cultivation. However, due to recent flood damage and conversion to domestic uses, agricultural acreage is presently about 500-600 acres. It is estimated that about 225 of these acres are irrigated with approximately 1,500 acre-feet of surface water diverted from the Virgin River.

The location of surface water resources for each basin in the planning area are shown on surface water condition maps, and maps showing perennial and intermittent streams and major springs. Tables with data on streamflow, flood ALERT equipment, reservoirs, stockponds and springs are also presented in the basin sections (6.1 – 6.6).

Groundwater

Groundwater is the principal water supply in the planning area where it is pumped from relatively shallow local aquifers or from deep regional aquifers. Groundwater pumpage averaged about 5,100 acre-feet during the period 2001 to 2003. Groundwater is a supply for municipal, industrial and agricultural users in the planning area. Aquifer depth is a significant factor in groundwater availability in the area since it is both expensive to drill wells and to pump water to the surface. Groundwater is pumped from depths exceeding 2,000 feet below land surface at Tusayan and Williams. In addition, well yields from sedimentary rocks of the deep regional aquifers are generally low unless fractures or faults are encountered. The median yield of 16 wells in the Coconino Plateau Basin completed in sedimentary rock aquifers is about 45 gpm.

Areas of unconsolidated sediments are relatively limited as shown on the groundwater conditions maps for each basin in sections 6.1-6.6. Extensive areas of unconsolidated sediments that comprise basin fill aquifers are found only in the western portions of the Virgin River and Grand Wash basins. Other basin fill aquifers in the planning area are generally narrow and bordered by low water yielding consolidated rocks. Areas of relatively high well yield include basin-fill deposits and the Muddy Creek Formation in the Virgin River Basin with a median well yield of 650 gpm based on data from 53 wells.

Few hydrologic studies have been conducted in the planning area and as a result, there is uncertainty regarding groundwater resources including recharge rates and groundwater in storage. Estimates of both aquifer recharge and storage are only available for the Virgin River Basin and estimates of groundwater in storage are only available for the Coconino Plateau and Paria basins.

In order to better understand the water supply situation in areas of the state where data are lacking, the Department has established automated groundwater monitoring sites that record water levels in wells. This information is available through an interactive map on the Department's website to allow access to local information for planning, drought mitigation and other purposes (www.azwater.gov/dwr/). These devices were located based on areas of growth, subsidence, type of land use, proximity to river/stream channels, proximity to water contamination sites or areas affected by drought.

Figure 1-18 of Volume 1 of the Atlas shows the location of automatic water-level recording sites as of 2005. At that time there were four sites in the planning area, three of which were USGS sites. There is currently one automated Department-operated site in the planning area located west of Littlefield in the Virgin River Basin.

Index well hydrographs, which display historic water level behavior in 14 index wells in the planning area (primarily in the Virgin River Basin) are also available at the same web location through an interactive map. Information on major aquifers, well yields, estimated natural recharge, estimated water in storage, aquifer flow direction, and water level changes are found in groundwater data tables, groundwater conditions maps, hydrographs and well yield maps for each basin in sections 6.1-6.6.

<u>Municipal and Industrial Supply</u>

With the exception of Fredonia, which utilizes surface water to meet about half of its demand and Grand Canyon Village, all other large communities in the planning area rely on groundwater supplies. Although groundwater may be difficult to access in many parts of the planning area, it is more reliable than the currently limited surface water supplies, particularly during drought. Since 1999, the City of Williams has drilled four wells, three of which have static water levels greater than 2,700 feet below land surface, as a backup to their surface water supplies. Some of the well drilling attempts have been unsuccessful. As of 2002, Williams had spent about seven million dollars to drill six wells, three of which are producing (Pinkham and Davis, 2002). The City currently has four operational wells but one yields only 40 gpm, and another has poor water quality with elevated concentrations of dissolved oxygen, metals and arsenic. Tusayan relies on two 3,000-foot deep wells in the Redwall-Muav aquifer as its primary water supply but also maintains a fleet of semi-tankers for emergency trucking of water if necessary (HydroResources, 2007). Groundwater is also an industrial supply for two golf courses in the Virgin River Basin.

<u>Agricultural Supply</u>

Groundwater is an agricultural water supply primarily in the Littlefield and Beaver Dam area in the Virgin River Basin. It is also used to a lesser degree for agricultural irrigation in the Kanab Plateau Basin at Colorado City, Moccasin/Kaibab and Cane Beds areas. In general, use of groundwater for irrigation is declining in the planning area.

Effluent

Due to the relatively limited groundwater and surface water supplies in the Coconino Plateau Basin, innovative reuse of effluent is occurring at several locations. About 3% of the total water demand is met by effluent. Effluent is used for golf course irrigation and municipal uses totaling about 270 acre-feet annually. Effluent supplies about half of the water requirements of the Elephant Rock Golf Course at Williams. Effluent generated at Tusayan is reused for toilet flushing in hotels and businesses and for landscape irrigation. Wastewater at the South Rim of the Grand Canyon is reused for toilet flushing, landscape irrigation and other uses. At Valle, effluent is used for landscape irrigation and fire protection.

Contamination Sites

Sites of environmental contamination may impact the use of some water supplies. An inventory of Department of Defense (DOD), Resource Conservation and Recovery Act (RCRA), Superfund (Environmental Protection Agency designated sites), Water Quality Assurance Revolving Fund (WQARF, state designated sites), Voluntary Remediation Program (VRP) and Leaking Underground Storage Tank (LUST) sites was conducted for the planning area. Of these various contaminated sites, LUST and VRP sites are found in the planning area. Table 6.0-7 lists the contaminant and affected media and the basin location of the single VRP site. The location of all contamination sites in the planning area is shown on Figure 6.0-12.

Table 6.0-7 Active contamination sites in the Western Plateau Planning Area

SITE NAME	MEDIA AFFECTED AND CONTAMINANT	GROUNDWATER BASIN
Voluntary Remediation Sites		
Heliport Lease Lot #1, Grand Canyon	Soil, Groundwater - Jet A Fuel, Hydrocarbons	Coconino Plateau

Sources: ADEQ 2002, ADEQ 2006a, ADEQ 2006b

There are 27 active LUST sites in the planning area. There are 11 sites at Fredonia, six at Jacob Lake, five at Williams, three at Tusayan, and one each at Cameron and Wahweap. The active VRP site is a heliport site at Tusayan in the Coconino Plateau Basin where soil and groundwater has been contaminated with hydrocarbons and jet fuel. The VRP is a state administered and funded voluntary cleanup program. Any site that has soil and/or groundwater contamination, provided that the site is not subject to an enforcement action by another program, is eligible to participate. To encourage participation, ADEQ provides an expedited process and a single point of contact for projects that involve more than one regulatory program (Environmental Law Institute, 2002).

6.0.7 Cultural Water Demand

Several recent studies provide detailed information on cultural water uses in the Coconino Plateau Basin. These studies are primarily related to developing additional water supplies to meet future water demands and include the North Central Arizona Water Supply Study (USBOR, 2006), North Central Arizona Water Demand Study, (Pinkham and Davis, 2002), Grand Canyon National Park Water Supply Appraisal Study (USBOR, 2002) and the EIS for Tusayan Growth (USDA, 1999).

Total cultural water demand in the Western Plateau Planning Area averaged approximately 8,800 acre-feet per year during the period from 2001-2003. As shown in Figure 6.0-13, the agricultural demand sector is the largest use sector with approximately 4,500 acre-feet of demand, 51% of the total. With the exception of small pastures, agricultural demand occurs only in the Kanab Plateau and Virgin River basins. About 44% of this agricultural demand is met by surface water diverted

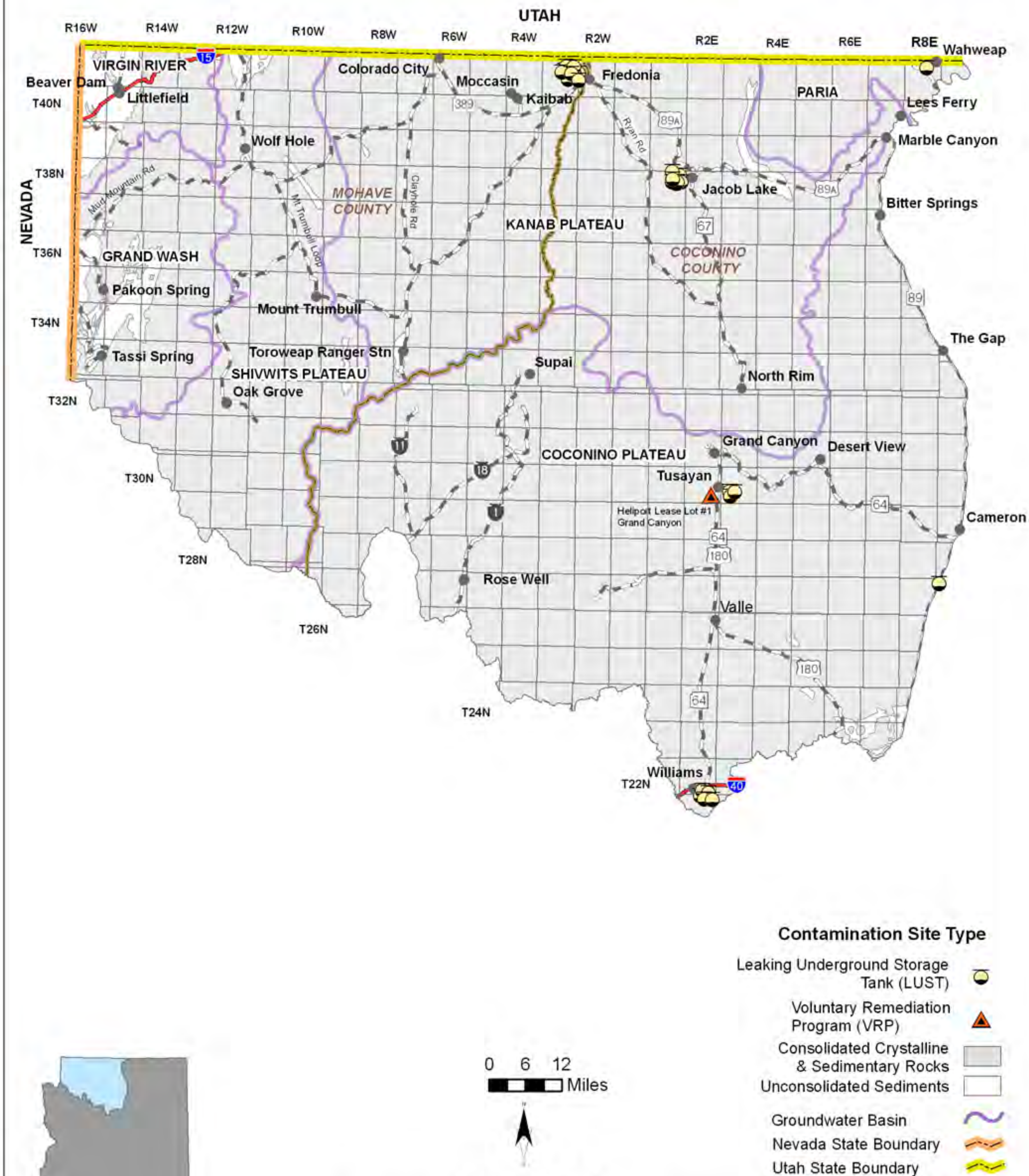
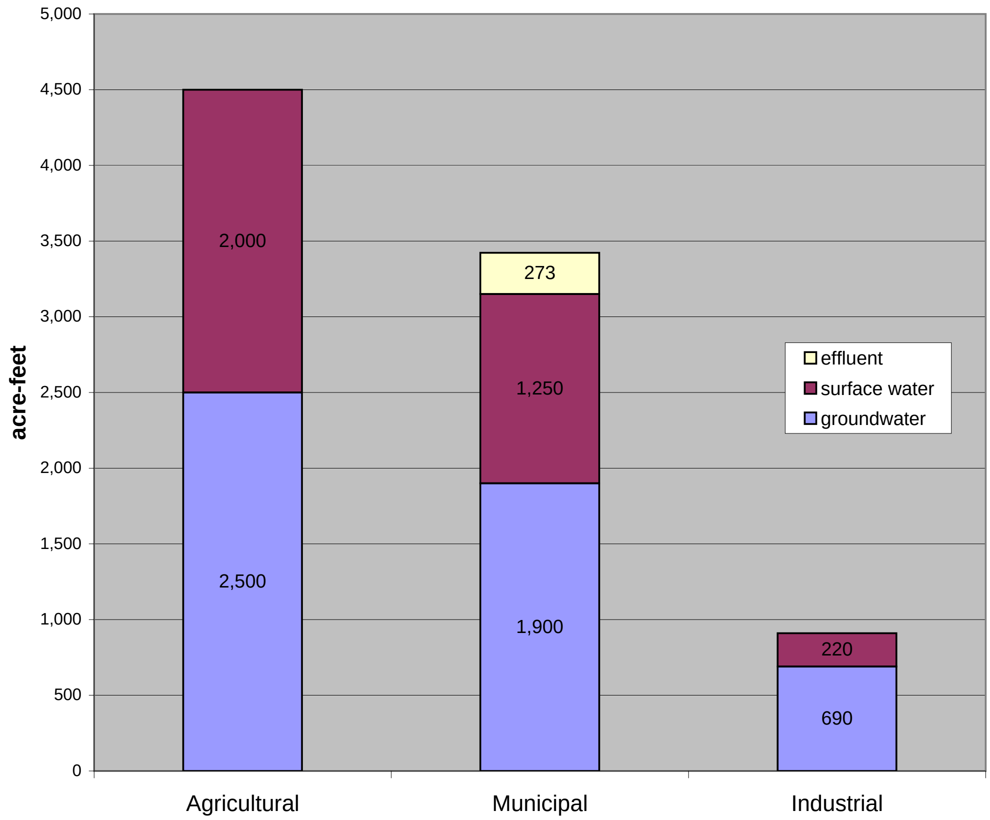


Figure 6.0-9
Western Plateau Planning Area Contamination Sites

from the Virgin River and Kanab Creek. Municipal demand represents about 39% of the total planning area demand with an average of 3,400 acre-feet during the period 2001-2003. Municipal demand is primarily met by groundwater and the municipal sector is the only sector that utilizes effluent. Industrial demand, primarily related to golf course irrigation, accounted for 900 acre-feet, 10% of the total demand during this period. Tribal water demand is included in these totals.

Figure 6.0-13 Western Plateau Planning Area Average Cultural Water Demand by Sector, 2001-2003

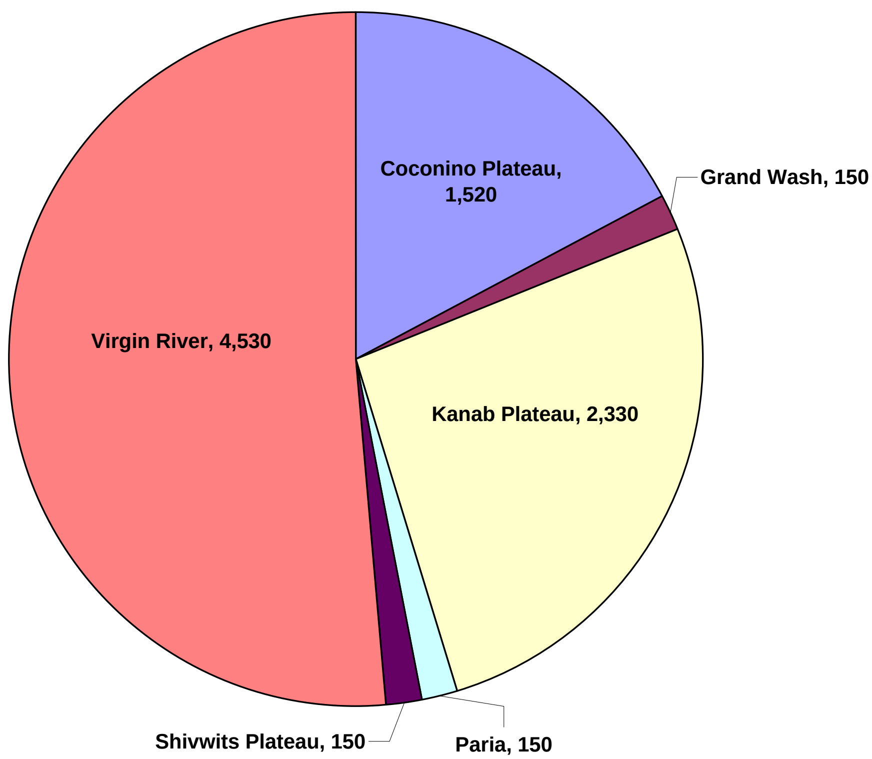


Cultural demand volumes vary substantially between planning area basins and ranges from 150 acre-feet a year in several basins to over 4,500 acre-feet a year in the Virgin River Basin (see Figure 6.0-14).

Tribal Water Demand

The largest Indian reservation in the planning area is the western portion of the Navajo Reservation, the largest reservation in terms of size in Arizona. All of the Havasupai and Kaibab-Paiute Reservations and the eastern portion of the Hualapai Reservation are also within the planning area. The portion of the Hualapai Reservation within the planning area is sparsely populated and its water demand is not known. Total tribal water demand in the planning area is estimated to be less than 450 acre-feet per year.

Figure 6.0-14 Average total basin water demand per year in acre-feet, 2001-2003



Water demand on the portion of the Navajo Reservation within the Western Plateau Planning Area is associated with domestic and tourism-related uses at several communities including Cameron, Gray Mountain, Cedar Ridge and Bodeway (The Gap). Stockwatering is also a likely use. Approximately 250 acre-feet is used annually in this area (USBOR, 2006).

The Kaibab-Paiute Reservation contains five villages, the largest of which is Kaibab. The Tribe maintains its tribal headquarters, a visitor's center and other services adjacent to Pipe Springs National Monument near the village of Kaibab. The tribal economy is centered on livestock and tourism as well as agriculture. The tribe owns a 1,300 tree fruit orchard and may expand agricultural activities (ITCA, 2003). Demand is estimated at less than 100 acre-feet per year. The nearby community of Moccasin is not located on reservation land and has been the site of the Mohave County Consolidated Court for over 50 years, serving all of Mohave County north of the Colorado River.

The Havasupai use surface water from Havasu Creek and from wells in shallow stream alluvium along the creek to support the community of Supai and tourism activities. There is also a small amount of farming on the reservation and stock watering. Tourism is the economic base for the tribe with more than 12,000 annual visitors to nearby Havasu Falls (ITCA, 2003). Water demand is likely less than 100 acre-feet per year on the reservation.

Municipal Demand

Municipal demand is summarized by groundwater basin and water supply in Table 6.0-8. Average annual demand during 2001-2003 was over 3,400 acre-feet. Fifty-five percent of the municipal demand is met by groundwater. Surface water is used in the Coconino Plateau Basin by Williams and Grand Canyon National Park-South Rim, and in the Kanab Plateau Basin by Fredonia, Grand Canyon National Park-North Rim, Jacob Lake and in the vicinity of Marble Canyon. Effluent is used for golf course irrigation in Williams, toilet flushing and irrigation at Tusayan and irrigation and fire protection at Valle.

Table 6.0-8 Average annual municipal water demand in the Western Plateau Planning Area (2001-2003) in acre-feet

Basin	Groundwater	Surface Water[1]	Effluent[2]	Total
Coconino Plateau	300	950	273	1,523
Grand Wash	<300			<300
Kanab Plateau	1,000	300		1,300
Paria	<300			<300
Shivwits Plateau	<300			<300
Virgin River	<300			<300
Total Municipal	1,900	1,250	273	3,423

Sources: USGS 2005b, ADWR 2005c
Notes: Volume <300 acre-feet assumed to be 150 acre-feet for computation purposes
[1] Shown on Table 6.0-8 is water utilized within the basin. The Cultural Demand Tables for the Kanab Plateau and Coconino Plateau basins in Sections 6.1.8 and 6.3.8 reflect water withdrawn in the basins.
[2] Effluent figures are for golf course, turf irrigation and municipal reuse in Tusayan, Grand Canyon Village and Williams in 2006

Primary municipal demand centers are Colorado City, Fredonia, Grand Canyon National Park, Tusayan and Williams. It is estimated that about 65% of the planning area population is served by a water provider. Six water providers in the planning area served 100 acre-feet or more of water in 2003. These providers and their demand in 1991, 2000 and 2003 are shown in Table 6.0-9. In 2003, municipal utilities served the communities of Fredonia and Williams. Municipally-owned systems have more flexible water rate-setting ability than private water companies, which are regulated by the Arizona Corporation Commission. In addition, municipal utilities have the authority to enact water conservation ordinances. These authorities may enable municipal utilities to better manage water resources within water service areas. Water provider issues are discussed in section 6.0.8.

City of Williams

The City of Williams was until recently completely reliant on surface water. Due to drought conditions which impacted surface water supplies, Williams has developed a groundwater system to use during periods when reservoir levels are low or to blend with surface water to aid in the water treatment process. In 2003, Williams used about 590 acre-feet of water- 336 acre-feet of surface water and 254 acre-feet of groundwater. Annual water demand and the supply used fluctuates from year to year. In 2005, Williams used a total of just 386 acre-feet of which only 29 acre-feet was groundwater (City of Williams, 2007).

Table 6.0-9 Water providers serving 100 acre-feet or more water per year in 2003, excluding effluent, in the Western Plateau Planning Area

Basin/Water Provider	1992 (acre-feet)	2000 (acre-feet)	2003 (acre-feet)
Coconino Plateau Basin			
City of Williams	450	620	590
Grand Canyon National Park Water Utility - South Rim	528	528	528
HydroResources-Town of Tusayan	135	125	129
Kanab Plateau Basin			
Centennial Park DWID - Colorado City	NA	NA	613
Fredonia Water Department	NA	417	440
Twin City Water Company - Colorado City	NA	NA	960

Sources: ADWR 2005c, ADWR 2004, City of Williams 2006, Coconino County 1997, Town of Colorado City 2006

NA = Not Available

Notes: Williams began using groundwater in 2000. Grand Canyon National Park receives its water from Roaring Springs in the Kanab Plateau Basin, about 88% of the total demand for the Park is used at the South Rim. In 1992 water in Tusayan was provided by the Canyon Squire Inn well (64 af), water hauled from Williams and Bellemont (40 af) and Grand Canyon National Park (30 af). Estimate of water served by Centennial Park DWID includes some water use for agriculture. Fredonia served 440 af in 2003, however, 220 af is water from Utah. Twin City Water Company water use is from 2006 and includes water from wells in Utah.

Municipal uses include residential, commercial and the only municipal golf course in the planning area. The Elephant Rock Golf course uses approximately half surface water and half effluent for irrigation. As the “Gateway to the Grand Canyon”, tourism is an important part of the local economy with hotels, restaurants, gas stations and other services. Williams maintains a metered standpipe for water haulers, restricted to households built as of June 2000. In 2000, Williams had 495 registered non-commercial water hauling customers. Some of the water used in the unincorporated residential community of Red Lake, located north of Williams, is hauled from Williams. Use of the standpipe service to commercial haulers is restricted during drought (Pinkham and Davis, 2002). While growth in Williams has been relatively slow, it has approved water allocations to more than 1,000 future lots. Expansion of both its water treatment plant and wastewater treatment plant may be needed in the near future. Because much of the area surrounding Williams relies on hauled water and delivers septic tank waste to the city wastewater treatment plant, the City is in the position of providing these services outside of its service area.

<u>Grand Canyon National Park</u>

Grand Canyon National Park, with about five million visitors a year and a year round population of almost 1,500 at Grand Canyon Village on the South Rim, is one of the largest municipal users in the planning area with about 600 acre-feet of surface water used in 2003. The South Rim receives most of the Park’s visitors and uses 90% of the water. Seasonal employees at Grand Canyon Village increase the summer population by about 40%. The Village includes a school, medical clinic, fire station, administrative offices and other services in addition to hotels, restaurants and campgrounds. By contrast, the North Rim is closed from mid-October to mid-May, has limited services compared to the South Rim and receives one-tenth the number of visitors. (Pinkham and Davis, 2002).

Grand Canyon National Park Water Utility services all the developed areas within the Park boundaries using water transported from Roaring Springs located below the North Rim in the Kanab Plateau Basin. The utility serves the South Rim, Desert View, North Rim, Roaring Springs, Phantom Ranch and Indian Gardens and provides hauled water to four sites on the South Rim that are not connected to the distribution system (NPS, 2006).

Some of the treated wastewater from the South Rim is reused for toilet flushing at the visitor center and employee rest rooms, to wash down portions of a kennel, for the railroad steam engine, dust control, revegetation efforts and on a small amount of turf at the El Tovar Lodge. While the reclaimed water distribution system is relatively extensive, one-site plumbing is incomplete. It is estimated that about 130 acre-feet of effluent is used annually at the South Rim.

<u>Tusayan</u>
The small, unincorporated community of Tusayan is located about a mile south of the entrance to the South Rim of Grand Canyon National Park. It is surrounded by public land and has a population of about 560. Tusayan's economy is based on tourism including hotels, restaurants, an airport and visitor service establishments (Pinkham and Davis, 2002).

HydroResources-Tusayan serves about seventy-five percent of the water demand at Tusayan utilizing two 3,000 foot deep wells that produce 65 to 80 gallons per minute. It delivers about 130 acre-feet of groundwater annually. Other water systems are ADOT, which serves the Grand Canyon Airport, and Anasazi Water (HydroResources, 2007). Anasazi Water has one well, receives some water from HydroResources and uses a relatively small amount of hauled water from Williams or Valle. Both HydroResources and Anasazi Water wholesale water to the Tusayan Water Development Association, which bills water customers but does not operate the water systems. The two systems are interconnected to ensure uninterrupted service to the community and HydroResources owns a well in Valle from which water may be trucked to Tusayan in the event of an emergency. The water systems relied heavily on hauled water prior to 1995 when wells and reclaimed water began to be used (Pinkham and Davis, 2002).

All water used indoors in Tusayan is treated at the South Grand Canyon Sanitary District wastewater treatment plant. Water is treated to ADEQ A+ standards and is used extensively for toilet flushing and irrigation. In 2001, almost 70 acre-feet of effluent was reused. It is estimated that reclaimed water use accounts for 30-50 percent of the total water use at some of the hotels (Pinkham and Davis, 2002).

The Grand Canyon Airport demand is about 10 acre-feet per year. A rainwater collection system, consisting of 5 acres of Hypalon plastic, provides potable water to the terminal, office, hangar facilities and a dozen homes. The airport also uses reclaimed water for irrigation (Pinkham and Davis, 2002). The airport has a connection to the HydroResources water system but rarely needs additional water. However, in 2004, HydroResources sold about 6 acre-feet of groundwater to the airport (HydroResources, 2007).

<u>Colorado City</u>
Colorado City is located in the Kanab Plateau Basin in Mohave County on the northern border

of Arizona, adjacent to Hildale, Utah. The two communities have close cultural and economic ties, with nearly half of the population employed in Hildale. The community was initially settled by ranchers in the early 1900's but around 1930 a group of religious fundamentalists from Utah settled in the area and played a major part in shaping the present-day community (USDOI, 2007). Colorado City is the largest community and municipal demand center in the planning area with over 1,600 acre-feet of annual demand served by two systems and a population of more than 3,300.

Most of Colorado City is served water pumped from wells owned by Twin City Water Works, which also serves Hildale Utah. Some of the Twin City Water Works wells are located in Arizona. The City buys water wholesale from Twin City Water Works, treats it to drinking water standards, and delivers it to customers through its water delivery infrastructure. The southeastern part of Colorado City is served by Centennial Park Domestic Water Improvement District, which also provides water for agricultural irrigation. Municipal water uses include residential, commercial and light manufacturing. The wastewater treatment plant in Colorado City was closed in 2002 and wastewater is now treated at a plant in Hildale.

Fredonia

Fredonia, in the Kanab Plateau Basin is the largest town in Coconino County on the Arizona Strip. It was founded in 1885 with an economy based on agriculture, timber and mining. Its sawmill closed in 1995 and tourism, government activities and agriculture are the current economic drivers. The population of Fredonia declined between 1990 and 2000 by about 14% but is now slowly increasing. In 2003, about 440 acre-feet of water was served by the municipal utility. About half of the Town's water supply is from springs in Arizona and the remainder is water transported by pipeline from Utah. Approximately 160 acre-feet of effluent is produced at Fredonia but not reused.

Other Communities

The communities of Beaver Dam, Littlefield, Scenic and the surrounding area in the Virgin River Basin are experiencing development pressure due primarily to the rapidly growing community of Mesquite, Nevada. These communities provide housing for much of Mesquite's workforce and for retirees (USDOI, 2007). Currently, the area is served by private water systems or domestic wells. There are several pending applications for water adequacy determinations in the area, the largest of which is an Analysis of Adequate Water Supply for the Beaver Dam Ranch Development totaling 5,300 acre-feet per year. This and other planned developments will result in substantial increases in municipal water demand in the Virgin River Basin from the current demand of less than 300 acre-feet a year. In anticipation of development, some agricultural lands north of Beaver Dam Wash and near Littlefield have gone out of production.

Valle, located between Williams and Tusayan, is a small but rapidly growing community served by two water systems with wells over 3,000 feet deep. One of these systems is owned by the Grand Canyon Inn, which also operates a wastewater treatment plant and a standpipe for water haulers. The Inn uses wastewater to irrigate landscaping at the hotel and for fire protection. The other system, HydroResources-Valle serves the Grand Canyon Valle Airport, a mobile home park and operates two standpipes for water haulers. A small wastewater treatment plant serves users on this system and effluent is used to irrigate a ballpark. The area surrounding Valle is primarily composed of large lot development without sewer or water service. Most residents must haul water and use septic systems for wastewater disposal. Despite the lack of services, there is significant subdivision activity in the area (Pinkham and Davis, 2002). The community grew by 334% between 1990 and 2000.

Agricultural Demand

Agricultural demand in the planning area is about 4,500 acre-feet a year, primarily for pasture irrigation (Table 6.0-10). Aside from small domestic pastures and gardens, agricultural irrigation is found only in the Kanab Plateau and Virgin River basins. It should be noted that the data source for the cultural demand maps in the groundwater basin sections is from satellite imagery collected between 1999-2001 and may not accurately represent agricultural demands in the planning area.

Table 6.0-10 Agricultural demand in the Western Plateau Planning Area

	1991-1995 (acre-feet)	1996-2000 (acre-feet)	2001-2003 (acre-feet)
Kanab Plateau			
Groundwater	1,500	1,500	<1,000
Surface Water	<1,000	<1,000	<1,000
Total	2,000	2,000	1,000
Virgin River			
Groundwater	7,800	8,300	2,000
Surface Water	5,800	6,200	1,500
Total	13,600	14,500	3,500

Source: USGS 2005c, ADWR 2005d
Notes: Volume <1,000 acre-feet assumed to be 500 acre-feet for computational purposes

There is considerable uncertainty about the amount of acreage currently in production in the Kanab Plateau Basin. Observations in the Colorado City, Cane Beds (east of Colorado City) and Fredonia areas suggest that in the summer of 2007 there was considerably less land irrigated than historic levels. It is estimated that current agricultural demand in the basin is about 1,000 acre-feet a year. About half the agricultural demand occurs in the Fredonia area, primarily within the boundaries of the Fredonia Consolidated Irrigation and Manufacturing Company District. The District owns and operates the Fredonia Dam, constructed in 1918, and a concrete-lined distribution ditch. District lands are located primarily east of Kanab Creek south of the town. Historically, the district delivered surface water diverted from Kanab Creek and it is assumed that this is still the source of water (ADWR, 1998). Irrigation in the Colorado City and Cane Beds area is assumed to be less than 1,000 acre-feet of groundwater a year. Large fallow areas, previously irrigated with center pivot systems were observed in the Colorado City area in summer 2007. There is a small amount of agricultural activity, including a 1,300 tree fruit orchard, on the Kaibab-Paiute Indian Reservation and in nearby Moccasin. Estimated groundwater demand is about 50 acre-feet a year.

In the Virgin River Basin, irrigation demand has declined from an annual average of 14,500 acre-feet during the period 1996-2000 to an annual average of 3,500 acre-feet during 2001-2003. This decline has occurred due to recent flood damage along the Virgin River and Beaver Dam Wash and to urbanization. It is estimated that about 525 acres are still in production in the Littlefield/Beaver Dam area (Kyle Spencer, NRCS, personal communication 3/25/05). With the exception of a small nursery operation at Beaver Dam, most of the irrigated land in the area is pasture.

Industrial Demand

Industrial demand in the planning area is relatively small, averaging about 900 acre-feet annually during the period 2001-2003. As shown in Table 6.0-11, quantified industrial demand in the planning area consists of two golf courses served by facility water systems and a small dairy. Both industrial golf courses are in the Virgin River Basin and use both surface water and groundwater. The Meadowayne Dairy, located on the north side of Colorado City in the Kanab Plateau Basin has an annual demand of about 30 acre-feet.

Table 6.0-11 Industrial demand in selected years in the Western Plateau Planning Area

	1991	2000	2003
Type	**Water Use (acre-feet)**		
Golf Course Total	**880**	**880**	**880**
Virgin River			
Groundwater	660	660	660
Surface Water	220	220	220
Dairy/Feedlot Total	**30**	**30**	**30**
Kanab Plateau			
Groundwater	30	30	30

Source: ADEQ 2005, ADWR 2005e, USGS 2005b

Golf courses in the planning area are shown in Table 6.0-12. Hamilton Ranch Golf Course is located in the community of Beaver Dam. Flooding in 2006 washed out all but 8 holes. Irrigation of the course uses about 220 acre-feet/year of groundwater and surface water diverted from Beaver Dam Wash. The other industrial golf course, The Palms, located in Scenic adjacent to the Nevada state line, is an 18-hole course that uses about 440 acre-feet/year of groundwater. The only other golf course in the planning area is Elephant Rock, a municipally-served golf course at Williams with an annual demand of about 150 acre-feet met by a combination of effluent and untreated surface water.

Table 6.0-12 Golf course demand in the Western Plateau Planning Area

Facility	Basin	# of Holes	Demand (acre-feet)	Water Supply
Elephant Rock Golf Club	Coconino Plateau	18	150	SW/Effluent
Hamilton Ranch*	Virgin River	8	220	GW/SW
The Palms Golf Course*	Virgin River	18	441	GW

Source: ADWR 2005e
Notes:
* These golf courses are served by their own wells and, therefore, considered to be industrial users

There is additional industrial demand in the planning area not reflected in the table, primarily sand and gravel operations in the Virgin River Basin and elsewhere. Some of the operations are identified on the cultural demand maps. Water is used for aggregate washing, dust control, vehicle washing and equipment cooling. Typically, relatively little water is consumed at these sites.

The three small mines shown on the Kanab Plateau Basin cultural demand map are uranium mines (Figure 6.3-11). Not all uranium mines are shown. Denison Mines owns the Arizona One mine with plans to begin mining in 2008 as well as two other mines, Canyon and Pinenut, which could be operated in the future. At least eleven mining companies are currently exploring the Arizona Strip and placing claims on breccia pipes for the purpose of uranium mining. The highest grade uranium deposits in the United States occur in breccia-pipe environments in northwest Arizona. A breccia pipe is a vertical pipe-like column of broken rock. On the Colorado Plateau in northwestern Arizona, these pipes formed when sedimentary rocks collapsed into solution cavities in the underlying Redwall limestone. Mineralizing fluids passing through the pipes deposited metallic minerals, sometimes including uranium. A typical pipe is about 300 feet in diameter and can extend as much as 3,000 feet. (Wenrick, 2007) It is anticipated that if developed, these mining operations would involve minimal water use. Water is used primarily in ore processing, which would occur elsewhere. The minor amount of water needed for mining on site would come from stormwater collection and/or shallow groundwater encountered in perched aquifers on site. (Nyals Neimuth, ADMMR, personal communication, 6/07)

6.0.8 Water Resource Issues in the Western Plateau Planning Area

Water resource issues in the Western Plateau Planning Area have been identified in water resource studies, by community watershed groups, through the distribution of surveys, and from other sources. Issues and planning, conservation and research activities are discussed in this section.

Studies, Planning and Conservation

A number of water resource studies have been conducted in the planning area south of the Colorado River. Studies have been conducted in response to environmental concerns, growth and limited water supplies. A primary objective has been to better understand the water supply, water demand and hydrology of the area in order to develop a regional approach to water resource planning. A major effort has been the North Central Arizona Water Supply Study, which involved the cooperation of the Bureau of Reclamation, Navajo Nation, Hopi Tribe, Havasupai Tribe, the Grand Canyon Trust, City of Williams, the City of Flagstaff, the City of Page, Coconino County, the Department of Water Resources, the USGS and USFWS. The next step is to secure funding to conduct a feasibility study to evaluate water supply alternatives.

On the Arizona Strip, the EIS for the Grand Canyon-Parashant and Vermilion Cliffs national monuments and for other BLM lands (BLM, 2007) is a comprehensive study of much of the area north of the Colorado River. While the focus is on land management to preserve the objectives of the monuments and other areas, water resources and demands are included as a component of the cooperative management of the area.

The National Park Service has conducted numerous studies and management activities in Grand Canyon National Park and Glen Canyon National Recreation Area. The water resources of the Park have been of particular concern given development on the South Rim and nearby areas and the potential impact of associated water development activities on seeps and springs in the Canyon. Development and implementation of new management strategies through the Adaptive Management Program will affect the environmental conditions downstream of Glen Canyon Dam throughout much of the planning area. There is a significant amount of interplay between resource development and environmental needs in the planning area given the significant amount of federally protected lands as parks, monuments, recreation areas and wilderness areas.

Because of relatively scarce water supplies, communities have made extraordinary efforts to develop new water supplies and reuse existing resources such as effluent and graywater. As mentioned previously, Grand Canyon Village and the community of Tusayan have taken extreme measures to conserve existing resources and reuse effluent for multiple purposes, including widespread use of effluent for toilet flushing. The rainwater harvesting system at the Tusayan airport, which supplies most of its potable supply, is unprecedented in Arizona. The City of Williams and Tusayan's well drilling programs are excellent examples of local efforts to improve supply reliability and better utilize available resources. The City of Williams water conservation program includes incentives to retrofit old plumbing fixtures and install drought tolerant landscaping and several other water systems in the planning area provide water conservation information to customers.

As mentioned in the population section, by January 2007, all large (>1,850 customers) community water systems in the state are required to submit System Water Plans. Small systems have until January 2008 to submit their plans. The plans are intended to reduce community water systems' vulnerability to drought, and to promote water resource planning to ensure that water providers are prepared to respond to water shortage conditions. Within the planning area plans have been submitted by the City of Williams and Colorado City, and by two small systems, Grand Canyon National Park and HydroResources-Tusayan. By July 1, 2007, all systems were required to submit an annual water use report with data on water pumped, diverted, received and delivered to customers.

Local Drought Impact Groups (LDIGs) are being formed in all counties across Arizona. LDIGs are voluntary groups that will coordinate drought public awareness, provide impact assessment information to local and state leaders, and implement and initiate local drought mitigation and response actions. These groups are coordinated by local representatives of Arizona Cooperative Extension and County Emergency Management and supported by ADWR's Statewide Community Water Planning Program.

To support the efforts of the LDIGs, professionals and residents are asked to provide monthly feedback on drought conditions throughout their county. Citizens may also participate with the LDIG by assisting with education and outreach efforts and recommending actions for drought mitigation and response. More information on LDIGs may be found at http://www.azwater.gov/dwr/drought/LDIG.html.

Watershed Groups

Several watershed groups affiliated with the Department's Rural Watershed Initiative Program have formed to address water resource issues. The two active groups, the Coconino Plateau Water Advisory Council and the Northern Arizona Municipal Water Users Association include not only part of the Western Plateau but also part of the Eastern Plateau and Central Highlands planning areas. A watershed group had formed in the Fredonia area, (the Arizona Strip Partnership), but is no longer active. A list of participants, activities and issues of all watershed groups in the planning area is found in Appendix B.

The Colorado River is a significant political, social and planning barrier as well as a physical barrier, and the area south of the River has different water resource concerns compared to areas north of the river. North of the River, the Arizona Strip is sparsely populated with few population centers. Colorado City, the largest community, has not identified any significant regional water resource issues. The Virgin River Basin is somewhat physically isolated from the rest of the Arizona Strip, and while experiencing rapid population growth, contains no incorporated communities or large water companies. However, as discussed below, a local group has formed to oppose an application to transport groundwater from the basin into Nevada, fearing the transportation will negatively impact local water supplies.

In March 2005, the Department received an application from Wind River Resources, L.L.C. to transport water from Beaver Dam Wash to Mesquite Nevada, pursuant to A.R.S. § 45-291 *et seq*. The statute allows for transportation of groundwater out of state, conditional on seven criteria that will be evaluated before the application can be approved or denied. The proposal calls for construction of three wells in the Mormon Wells area along Beaver Dam Wash to initially withdraw 800 acre-feet/year and up to 14,000 acre-feet per year by 2045, and transport it to the Virgin Valley Water District in Mesquite. The application proposes to use the water from Arizona to mix with the District's water, which has concentrations of arsenic in excess of the drinking water standard. The Office of Administrative Hearings held a three-day hearing in early March 2007 in Beaver Dam and took testimony and received briefs on the application. The record will remain open until October 10, 2007 for the filing of post-hearing briefs. The Administrative Law Judge has 20 days after the record closes to issue his recommended decision and the director of the Department has 30 days thereafter to issue his decision.

Primary issues identified by the Arizona Rural Watershed Initiative groups that pertain to the planning area are summarized as follows:

Growth:

Unregulated lot splits
Significant projected growth

Water Supplies and Demand:

Limited and deep groundwater supplies
Need access to water development on public lands
Limited groundwater data

Limited supplies to meet projected demands
Limited water resources to meet current demands
Numerous water haulers with few hauling stations that are sometimes cut-off during drought
Brackish groundwater (Arizona Strip)
Interstate stream issues (Arizona Strip)
Inadequate surface water supplies for agriculture (Arizona Strip)

Legal:

Unresolved Indian Water Rights claims
Proposed San Juan Paiute Indian Reservation (northeast portion of Coconino Plateau Basin)

Funding:

Limited funding resources for planning, projects, infrastructure and studies
High cost of water augmentation projects
Costs associated with hauling water
Infrastructure needs for private water companies

Drought:

Drought sensitive groundwater and surface water supplies

Environmental:

Potential for groundwater development to impact springs in Grand Canyon and Havasupai and Hualapai Indian Reservation water supplies

Other:

Unsafe dam issues (Williams and Fredonia)

Issue Surveys

The Department conducted a rural water resources survey in 2003 to compile information for the public and help identify the needs of growing communities. This survey was also intended to gather information on drought impacts to incorporate into the Arizona Drought Preparedness Plan, adopted in 2004. Questionnaires were sent to almost 600 water providers, jurisdictions, counties and tribes, and a report of the findings from the survey was subsequently completed (ADWR, 2004).

Only one water provider in the planning area responded to the 2003 survey. The Department conducted another, more concise survey of water providers in 2004. This was done to supplement the information gathered in the previous year in support of developing the Arizona Water Atlas, and to reach a wider audience by directly contacting each water provider. Through this effort, ten water providers in the Western Plateau Planning Area, with a total of approximately 2,400 service connections, participated and provided information on water supply, demand, and infrastructure and ranked a list of seven issues. There were five respondents from the Virgin River Basin, three from the Kanab Plateau Basin and two from the Coconino Plateau Basin.

With regard to a question of groundwater level trends in their service area, most respondents reported stable water levels as shown by basin with the corresponding number of respondents in Table 6.0-13. One respondent in the Kanab Plateau Basin reported falling water levels and one in the Virgin River Basin reported rising water levels.

Table 6.0-13 Groundwater level trends reported by 2004 survey respondents by groundwater basin (10 respondents)

Basin	Rising	Stable	Falling	Variable	Don't Know
Coconino Plateau		1			1
Kanab Plateau		2	1		
Virgin River	1	4			

Source: ADWR 2005c

Water providers were asked in the 2004 survey to rank 7 issues from 0 to 3 with 0 = no concern, 1 = minor concern, 2 = moderate concern and 3 = major concern. All water providers responded, but two reported no concerns. Results are shown in Table 6.0-14 for the eight providers that ranked issues of concern. The most highly ranked issue, inadequate capital for infrastructure improvements, was identified primarily by respondents located in the Virgin River Basin. Inadequate storage was primarily an issue in the Kanab Plateau Basin.

Table 6.0-14 Water resource issues ranked by 2004 survey respondents in the Western Plateau Planning Area (7 water providers)

Issue	Moderate concern	Major concern	Total	Percent of respondents reporting issue was a major or moderate concern
Inadequate storage capacity to meet peak demand	0	3	3	43%
Inadequate well capacity to meet peak demand	0	1	1	14%
Inadequate supplies to meet current demand	2	1	3	43%
Inadequate supplies to meet future demand	1	2	3	43%
Infrastructure in need of replacement	1	1	2	29%
Inadequate capital to pay for infrastructure improvements	0	5	5	71%
Drought related water supply problems	0	2	2	29%

Source: ADWR 2005c

6.0.9 Groundwater Basin Water Resource Characteristics

Sections 6.1 through 6.6 present data and maps on water resource characteristics of the groundwater basins in the Western Plateau Planning Area. A description of the data sources and methods used to derive this information is found in Section 1.3 of Volume 1 of the Atlas. This section briefly describes general information that applies to all of the basins and the purpose of the information.

This information is organized in the order in which the characteristics are discussed in Sections 6.1 through 6.6.

Geographic Features
Geographic features maps are included to present a general orientation to principal land features, roads, counties and cities, towns and places in the groundwater basin.

Land Ownership
The distribution and type of land ownership in a basin has implications for land and water use. Large amounts of private land typically translate into opportunities for land development and associated water demand, whereas federal lands are typically maintained for a purpose with little associated water use. State owned land may be sold or traded, and is often leased for grazing and farming. The extent of state owned lands is due to a number of legislative actions. The State Enabling Act of 1910 and the Act that established the Territory of Arizona in 1863 set aside sections 2, 16, 32 and 36 in each township to be held in trust by the state for educational purposes. Other legislation authorized additional state trust lands for specified purposes, which are identified for each basin (ASLD, 2006).

Climate
Climate data including temperature, rainfall, evaporation rates and snow are critical components of water resource planning and management. Averages and variability, seasonality of precipitation and long term climate trends are all important factors in demand and supply planning.

Surface Water Conditions
Depending on physical and legal availability, surface water may be a potential supply in a basin. Stream gage, flood gage, reservoir, stockpond and runoff contour data provide information on physical availability of this supply. Seasonal flow information is relevant to seasonal supply availability. Annual flow volumes provide an indication of potential volumetric availability.

Criteria for including stream gage stations in the basin tables are that there is at least one year of record, and annual streamflow statistics are included only if there are at least three years of record. There are different types of stations and those that only serve repeater functions were not included.

Flood gage information is presented to direct the reader to sources of additional precipitation and flow information that can be used in water resource planning. Large reservoir storage information provides data on the amount of water stored in the basin, its uses, and ownership. Because of the large number of small reservoirs, and less reliable data, individual small reservoir data is not provided. The number of stockponds is a general indicator of small scale surface water capture and livestock demand. Runoff contours reflect the average annual runoff in tributary streams. They provide a generalized indication of the amount of runoff that can be expected at a particular geographic location.

Perennial and Intermittent Streams and Major Springs
A map of perennial and intermittent streams is provided for each basin. For some basins, more

than one source of information was used. Stream designations may not accurately reflect current conditions in some cases. Spring data was compiled from a number of sources in an effort to develop as comprehensive a list as possible. Spring data is important to many researchers and to the environmental community due to their importance in maintaining habitat, even from small discharges.

Groundwater Conditions

Several indicators of groundwater conditions are presented for each basin. Aquifer type can be a general indicator of aquifer storage potential, accessibility of the supply, aquifer productivity, water quality and aquifer flux. Well yield information for large diameter wells is provided and is generally measured when the well is drilled and reported on completion reports. It was assumed that large diameter wells were drilled to produce a maximum amount of water and, therefore, their reported pump capacities are indicative of the aquifer's potential to yield water to a well. However, many factors can affect well yields including well design, pump size and condition and the age of the well. Reported well yields are only a general indicator of aquifer productivity and specific information is available from well measurements conducted as part of basin investigations.

Natural recharge is typically the least well known component of a water budget. Many of the estimates in the Atlas are derived from studies of larger geographic areas and all deserve further study. Similarly, estimates of storage are based on rough estimates and considerably more studies are needed in most basins. Components of storage include aquifer depth and specific yield.

Water level data is from measured wells, usually collected during the period when the wells were not actively being pumped or only minimally pumped. Depth to water measurements are shown on mapped wells if there was a measurement taken during 2003-2004. The basin hydrographs show water-level trends for selected wells over the 30-year period from January 1975 to January 2005. Not all basins have a sufficient number of representative hydrographs.

The flow directions that are shown generally reflect long-term, regional aquifer flow in the basin and are not meant to depict temporary or local-scale conditions. However, flow directions in some basins indicate how localized pumping has altered regional flow patterns.

Water Quality

Water quality conditions impact the availability of water supplies. Water quality data was compiled from a variety of sources as described in Volume 1 Section 1.3. The data indicate areas where water quality exceedences have previously occurred, however additional areas of concern may currently exist where water quality samples have not been collected or sample results were not reviewed by the Department (e.g. samples collected in conjunction with the ADEQ Aquifer Protection Permit programs). It is important to note also that the exceedences presented may or may not reflect current aquifer or surface water conditions.

Cultural Water Demand

Cultural water demand is an important component of a water budget. However, without mandatory metering and reporting of water uses, accurate demand data is difficult to acquire. Municipal demand includes water company and domestic (self-supplied) demand estimates. Basin demand information is from several sources in order to prepare as accurate an estimate as possible. Annual demand estimates have been averaged over a specific time period. This provides general trend information without focusing on potentially inaccurate annual demand estimates due to incomplete data.

Locations of major cultural water uses are primarily from a 2004 USGS land cover study using older satellite imagery that may not represent recent changes. The cultural demand maps provide only general information about the location of water users.

Effluent generation data was compiled from several sources to provide an estimate of how much of this renewable resource might be available for use. However, effluent reuse is often difficult both logistically and economically since a potential user may be far from the wastewater treatment plant.

Water Adequacy Determinations

Information on water adequacy and inadequacy determinations for subdivisions, with the reason for the inadequacy determination provides information on the number and status of subdivision lots. Listing the reason for the inadequacy identifies which subdivisions have a demonstrated physical or legal lack of water or may have elected not to provide the necessary information to the Department. Briefly, developers of subdivisions outside of AMAs are required to obtain a determination of whether there is sufficient water of adequate quality available for 100 years. If the supply is determined to be inadequate, lots may still be sold, but the condition of the water supply must be disclosed in promotional materials and in sales documents.

In addition to these subdivision determinations for which a water adequacy report is issued, water providers may apply for adequacy designations for their entire service area. If a subdivision is to be served water from one of these water providers, then a separate adequacy determination is not required. (See Appendix A, Volume 1 for more information about the Adequacy Program).

REFERENCES

Arizona Department of Economic Security (DES), 2005, Workforce Informer: Accessed August 2005 at www.workforce.az.gov

Arizona Department of Environmental Quality (ADEQ), 2006a, Active DOD, Superfund, WQARF, and LUST contamination sites in Arizona: GIS cover, received February 2006.

_____, 2006b, Brownfield Tracking System: Accessed June 2006 at www.azdeq.gov/ databases/ brownsearch.html.

_____, 2005, Active dairy farms & feedlots: Data file, received October 2005.

_____, 2002, The Status of Water Quality In Arizona – 2002: Volume 1. Arizona's Integrated 305(b) Assessment and 303(b) Listing Report

Arizona Department of Water Resources (ADWR), 2006, Assured and adequate water supply applications: Project files, ADWR Water Management Division

_____, 2005a, Database of instream flow applications: ADWR Office of Water Management

_____, 2005b, Registry of surface water rights: ADWR Office of Water Management.

_____, 2005c, Data from 2004 rural water provider questionnaire: ADWR Office of Resource Assessment Planning

_____, 2005d, Agricultural surface water use estimates: Unpublished analysis by ADWR Office of Resource Assessment Planning

_____, 2005e, Water use by golf courses in rural Arizona: Unpublished analysis by ADWR Office of Regional Strategic Planning

_____, 2005f, Water Protection Fund database: ADWR Office of Drought, Conservation and Riparian Planning

_____, 2004, Rural Water Resources Study-Rural Water Resources 2003 Questionnaire Report.

_____, 1998, Water Service Organizations in Arizona

_____, 1994a, Arizona Water Resources Assessment, Vol. II Hydrologic Summary.

Arizona Game and Fish (AZGF), 2006, California Condor Recovery: Accessed August 2007 at http://www.gf.state.az.us/w_c/california_condor.shtml

_____, 2004, Explore Arizona: Accessed January 2007 at http://explore.azgfd.gov

_____, 1997 & 1993, Statewide riparian inventory and mapping project: GIS cover.

Arizona State Land Department (ASLD), 2006, Historical overview-Land Grant and Designation of Beneficiaries: Accessed February 2006 at http://www.land.state.az.us/history.htm.

Bales, J.T. and R.L. Lacey, 1992, Geohydrologic Reconnaissance of Lake Mead National Recreation Area-Virgin River, Nevada, to Grand Wash Cliffs, Arizona, USGS Water Resources Investigations Report 91- 4185

Billingsley, G.H., Wellmeyer, J.L., 2003, Geologic Map of Mt. Trumbell 30x60 Quadrangle, Mohave and Coconino Counties, Northwestern Arizona: USGS Geologic Investigation Series I-2766.

Bills, D.J., Flynn, M.E., Monroe, S.A., in press, Hydrogeology of the Coconino Plateau and Adjacent Areas Coconino and Yavapai Counties, Arizona: USGS Scientific Investigations Report 2005-5222.

Bills, D.J., Flynn, M.E, 2002, Hydrologic Data for the Coconino Plateau and Adjacent Areas, Coconino and Yavapai Counties, Arizona: USGS Open-File Report 02-265.

Black, K.R. and S.J. Rascona, 1991, Maps Showing Groundwater Conditions in the Virgin River Basin Mohave County, Arizona, Lincoln and Clark Counties, Nevada—1991. Department of Water Resources Hydrologic Map Series Report Number 22

Brown, D. and Lowe, C., 1980, Biotic Communities of the Southwest: GIS Cover digitized by Arizona Game and Fish Department: Accessed in 2007 at http://www.dot.co.pima.az.us/gis/maps/mapguide

Brown, D., ed., 1982, Biotic Communities of the Southwest-United States and Mexico, Special Issue of Desert Plants, Volume 4. Numbers 1-4, Published by the University of Arizona for the Boyce Thompson Southwestern Arboretum

Bush, A. L. and M.E. Lane, 1980, Preliminary Report on the Mineral Resource Potential of the Vermillion Cliffs-Paria Canyon Instant Study Area, Coconino County, Arizona, and Kane County, Utah. USGS Open-File Report 80-1056

City of Williams, 2007, City of Williams System Water Plan submitted to ADWR

Coconino County, 1997, Tusayan Area Plan and Design Review Overlay, Area Plan Approved by the Coconino County Board of Supervisors April 7, 1995 & Amended May 5, 1997.

Cole, E. and Katzer, T., 2000, Analysis of Gains and Losses in Virgin River Flow between Bloomington, Utah, and Littlefield, Arizona: Southern Nevada Water Authority, Las Vegas, Nevada, 57 pp.

Dixon, G.L. and Katzer, T., 2002, Geology and Hydrology of the Lower Virgin River Valley in Nevada, Arizona, and Utah, Prepared for the Virgin Valley Water District

Environmental Law Institute, 2002, An Analysis of State Superfund Programs: 50 State Study, 2001 Update

Freilich, Leitner & Carlisle, 2005, Mohave County General Plan: Water Resources Element.

Grahame, J.D. and Sisk, T.D., ed. 2002. Canyons, cultures and environmental change: An introduction to the land-use history of the Colorado Plateau. Accessed July, 2007 at http://www.cpluhna.nau.edu/

Hannon, S., 2003, The 1983 Flood at Glen Canyon: Accessed August 2007 at www.glencanyon.org

Hart, R.J., Ward, J.J., Bills, D.J. and Flynn, M.E., 2002, Generalized Hydrogeology and Ground-Water Budget for the C Aquifer, Little Colorado River Basin and Parts of the Verde and Salt River Basins, Arizona and New Mexico: Water-Resources Investigations Report 02-4026.

HydroResources, 2007, Tusayan System Water Plan: Submitted to the ADWR.

Intertribal Council of Arizona (ITCA), 2003, Hualapai Indian Tribe, Kaibab-Paiute Indian Tribe: Accessed July, 2007 at www.itcaonline.com

Meko D. M., Woodhouse C. A., Baisan C. H., Knight T., Lukas J. J., Hughes M. K. and Salzer M. W., 2007, Medieval drought in the Upper Colorado River Basin, Geophys. Res. Lett. 34(10, L10705).

National Park Service (NPS), 2007, Grand Canyon - Nature and Science: Accessed July 2007 at http://www.nps.gov/grca/naturescience/index.htm

______, 2006 Grand Canyon National Park System Water Plan. Submitted to ADWR

______, 2005, The Geologic Story at Grand Canyon: Accessed July 2007 at http://www.nps.gov/archive/grca/grandcanyon/quicklook/Geologicstory.htm

Pinkham, R. and Davis, B., 2002, North Central Arizona Water Demand Study Phase 1 Report, submitted to the Coconino Plateau Water Advisory Council

Seaber, P.R., Kapinos, E.P. and Knapp, G.L., 1987, Hydrologic Unit Maps; U.S. Geological Survey Water-Supply Paper 2294, 63 pp.

Tellman, B., Yarde, R., and Wallace, M., 1997, Arizona's changing rivers: How people have affected rivers: Water Resources Research Center, University of Arizona, Tucson, Arizona

Trudeau, D.A, Hess, J.W., and Jacobson, R.L., 1983, Hydrogeology of the Littlefield Springs, Arizona.

Truini, M., Fleming, J.B. and Pierce, H.A., 2004, Preliminary Investigation of Structural Controls of Ground- Water Movement in Pipe Spring National Monument, Arizona, USGS Scientific Investigations Report 2004-5082

U.S. Bureau of Land Management (BLM), 2007, Arizona Strip Resource Management Plan Revision, Grand Canyon-Parashant National Monument Management Plan (jointly managed with the National Park Service), and Vermilion Cliffs National Monument Management Plan: Accessed August, 2007 at http://www.blm.gov/az/lup/strip/strip_plan.htm

______, 2006, Arizona Wilderness Areas: Accessed December 2006 at www.blm.gov/az/wildarea.htm

U.S. Bureau of Reclamation (USBOR), 2007a, Lake Powell-Glen Canyon Dam-Current Status: Accessed August 2007 at http://www.usbr.gov/uc/water/crsp/cs/gcd.html

______, 2007b, Draft Annual Operating Plan for Colorado River Reservoirs 2008, August 17, 2007.

______, 2007c, Glen Canyon Dam Adaptive Management Program: Accessed August 2007 at http://www.usbr.gov/uc/rm/amp/index.html

______, 2007d, Colorado River Interim Guidelines for Lower Basin Shortages and Coordinated Operations for Lakes Powell and Mead: Accessed August, 2007 at http://www.usbr.gov/lc/region/programs/strategies.html

______, 2007e, Colorado River Reservoir Operation: Development of Colorado River Interim Guidelines for Lower Basin Shortages and Coordinated Operations of Lake Powell and Lake Mead. Description of Preferred Alternative to be Considered in the Final Environmental Impact Statement

______, 2006, North Central Arizona Water Supply Study Report of Findings, 91pp

______, 2005, Glen Canyon Powerplant: Accessed August 2007 at http://www.usbr.gov/power/data/sites/glencany/glencany.html

______, 2002, Grand Canyon National Park Water Supply Appraisal Study, Coconino, Mohave, and Yavapai Counties, Arizona, Prepared for National Park Service Grand Canyon National Park, Grand Canyon, Arizona

U.S. Census Bureau, 2006, on-line data files: Accessed January 2006 at www.census.gov

U.S. Department of Agriculture (USDA), 2006, Forest Insect and Disease Conditions in the Southwestern Region, 2006

______, 1999, Executive Summary of the Final Environmental Impact Statement for Tusayan Growth Coconino County, Arizona

U.S. Department of Interior (USDOI), 2007, Proposed Resource Management Plan/Final EIS for the Arizona Strip Field Office, the Vermilion Cliffs National Monument, and the BLM Portion of Grand Canyon-Parashant National Monument, and a Proposed General Management Plan/Final EIS for the NPS Portion of the Grand Canyon-Parashant National Monument, Volumes 1&3

U.S. Forest Service (USFS), 2007, Wilderness Areas: Accessed March, 2007 at http://www.fs.fed.us/r3/

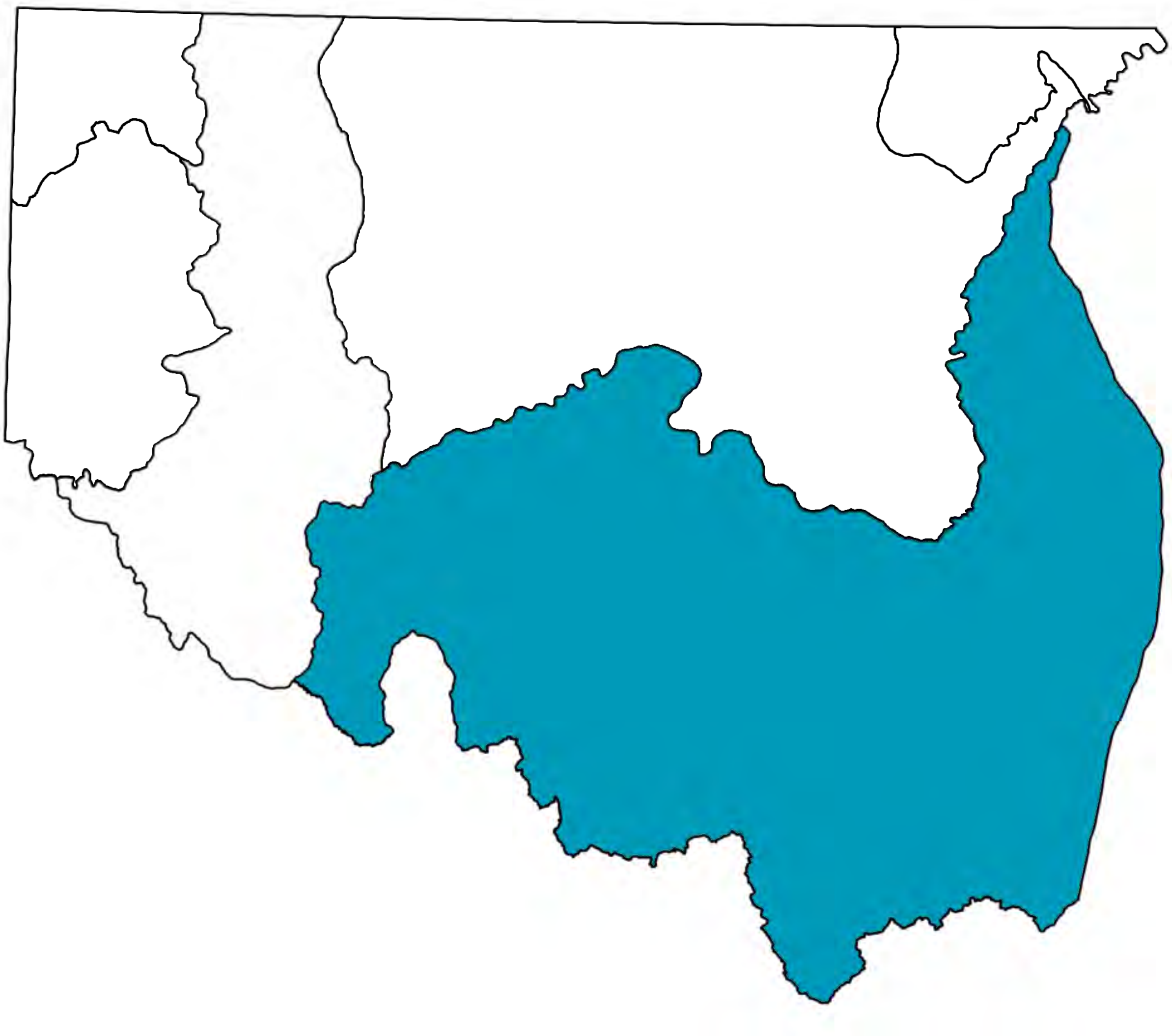
U.S. Fish and Wildlife Service (USFWS), 2006, Endangered Species List by County: Accessed July 2006 at www.fws.gov/arizonaes/documents/countylists and www.fws.gov/ifw2es/endangered species/lists/default.cfm.

U.S. Geological Survey (USGS), 2005a, 1:2,000,000-Scale Hydrologic Unit Boundaries: GIS Cover, accessed in 2007 at http://nationalatlas.gov/atlasftp.html?openChapters=chpwater#chpwater

_____, 2005b, Water withdrawals for irrigation, municipal, mining, thermoelectric-power, and drainage uses in Arizona outside of the active management areas, 2000-2005: Data file, received December 2005.

Wenrick, K.J., 2007, Projects: Uranium Mining in Arizona – High Grade and Safe. Accessed July, 2007 at http://www.libertystaruranium.com

Section 6.1
Coconino Plateau Basin



6.1.1 Geography of the Coconino Plateau Basin

The Coconino Plateau Basin, located in the western part of the planning area is 5,812 square miles in area and the largest basin in the planning area. Geographic features and principal communities are shown on Figure 6.1-1. The basin is characterized by high-elevation mountain ranges, plateaus and canyons. Vegetation types include Mohave and Great Basin desertscrub, plains grasslands, Great Basin conifer woodland and Rocky Mountain montane conifer forest. There are small areas of subalpine conifer forest and alpine tundra in the San Francisco Mountains in the southeast corner of the basin. (See Figure 6.0-9)

- Principal geographic features shown on Figure 6.1-1 are:
    - Principal basin communities of Tusayan and Williams
    - Other communities and places of Bitter Springs, Desert View, Cameron, Grand Canyon, Rose Well, Supai, The Gap and Valle
    - The Colorado River and Grand Canyon forming the northern basin boundary
    - Numerous streams that flow into the Colorado River including Diamond Creek, Havasu Creek and the Little Colorado River
    - Coconino Plateau in the center of the basin
    - Aubrey Cliffs in the eastern portion of the basin
    - San Francisco Peaks in the southeastern portion of the basin, including the highest peak in the basin and planning area, Mt. Humphries at 12,633 feet.

Figure 6.1-1
Coconino Plateau Basin
Geographic Features

6.1.2 Land Ownership in the Coconino Plateau Basin

Land ownership, including the percentage of ownership by category, for the Coconino Plateau Basin is shown in Figure 6.1-2. Principal features of land ownership in this basin are the large blocks of tribal lands and the checkerboard pattern of state trust and private land. A description of land ownership data sources and methods is found in Volume 1, Section 1.3.8. Land ownership categories are discussed below in the order of percentage from largest to smallest in the basin.

Indian Reservation

- 37.3% of the land is under tribal ownership.
- The basin includes all or parts of three reservations; the Hualapai Indian Reservation, the entire Havasupai Indian Reservation and the Navajo Indian Reservation.
- This basin contains the largest percentage of tribal lands in the planning area.
- Land uses include domestic, commercial, recreation and ranching.

Private

- 22.0% of the land is private.
- The majority of the private land is in the center of the basin and is interspersed with state trust lands.
- Land uses include domestic, commercial and ranching.

National Forest and Wilderness

- 17.8% of the land is federally owned and managed as National Forest and Wilderness.
- Forest lands in the basin are part of the Kaibab and Coconino National Forests.
- The basin contains approximately 25,000 acres in two wilderness areas, Kendrick Mountain in the Coconino and Kaibab National Forests and Kachina Peaks in the Coconino National Forest.
- Land uses include recreation, grazing and timber production.

State Trust Land

- 15.4% of the land is held in trust for the public schools and seven other beneficiaries under the State Trust Land system.
- Most state land is located in the center of the basin interspersed in a checkerboard pattern with private land.
- Primary land use is grazing.

National Park Service (NPS)

- 7.4% of the land is of the land is federally owned and managed by the National Park Service as the Grand Canyon National Park.
- Land uses include resource conservation and recreation.

U.S. Bureau of Land Management (BLM)

- 0.1% of the land is federally owned and managed by the Hassayampa Field Office of the Bureau of Land Management.
- The small portion of BLM land is southwest of the Grand Canyon.
- Primary land use is grazing.

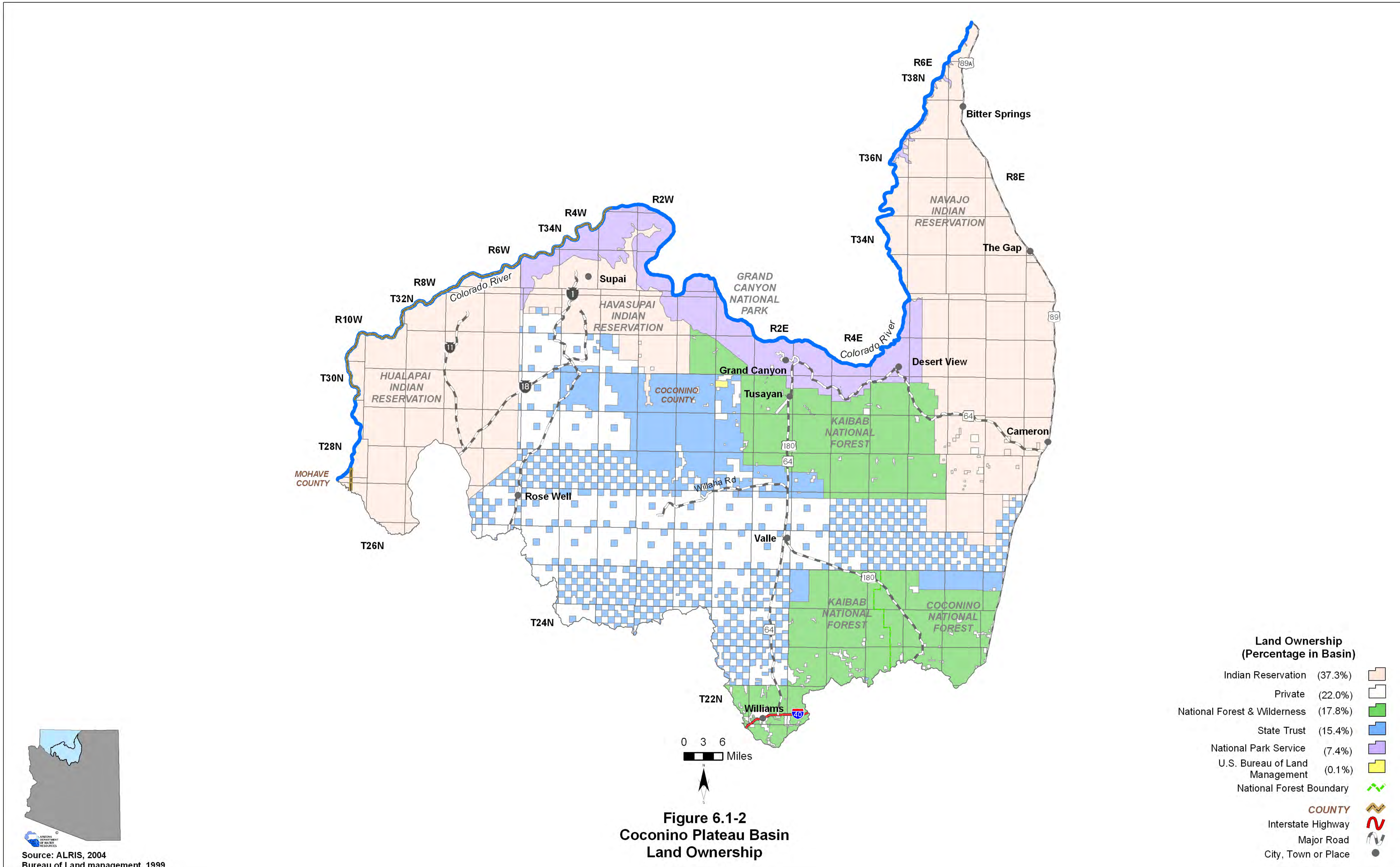


Figure 6.1-2
Coconino Plateau Basin
Land Ownership

6.1.3 Climate of the Coconino Plateau Basin

Climate data from NOAA/NWS Co-op Network, Evaporation Pan and SNOTEL/ Snowcourse stations are complied in Table 6.1-1 and the locations are shown on Figure 6.1-3. Figure 6.1-3 also shows precipitation contour data from the Spatial Climate Analysis Service (SCAS) at Oregon State University. The Coconino Plateau Basin does not contain AZMET stations. A description of the climate data sources and methods is found in Volume 1, Section 1.3.3.

NOAA/NWS Co-op Network

- Refer to Table 6.1-1A
- Temperatures at the five NOAA/NWS Co-op Network stations range from an average annual high of 83.0°F at Supai to an average annual low of 29.3°F at Grand Canyon National Park.
- All stations report highest average seasonal rainfall in the summer season (July-September) when about 32% of the annual rainfall occurs.
- The highest average annual precipitation is 21.37 inches at Williams and the lowest average annual precipitation is 8.76 inches at Supai.

Evaporation Pan

- Refer to Table 6.1-1B
- There is one evaporation pan station in the basin, Grand Canyon National Park 2. This pan is at 6,790 feet and has an annual evaporation rate of 44.04 inches.

SNOTEL/Snowcourse

- Refer to Table 6.1-1D
- There are four SNOTEL/Snowcourse stations in the basin, one at the Grand Canyon and the others located in the San Francisco Peaks area.
- The highest average monthly snowpack at most stations is in April.

SCAS Precipitation Data

- See Figure 6.1-3
- Additional precipitation data shows average annual rainfall as high as 40 inches at the southeastern tip of the basin and as low as four inches along the Colorado River.

Table 6.1-1 Climate Data for the Coconino Plateau Basin

A. NOAA/NWS Co-op Network:

Station Name	Elevation (in feet)	Period of Record Used for Averages	Average Temperature Range (in F)		Average Precipitation (in inches)				
			Max/Month	Min/Month	Winter	Spring	Summer	Fall	Annual
Grand Canyon N.P.	6,890	1971-2000	69.2/Jul	29.3/Jan	4.38	1.92	5.73	3.65	15.68
Grand Canyon N.P. 2	6,970	1971-2000	67.0/Jul	30.4/Jan	5.20	2.17	5.40	3.73	16.50
Grand Canyon N.P. 3	6,960	1957-1977[1]	69.0/Jul	30.5/Jan	2.92	1.84	3.89	3.87	12.51
Supai	3,200	1956-1987[1]	83.0/Jul	40.7/Jan	2.36	1.20	3.02	2.18	8.76
Williams	6,750	1971-2000	68.3/Jul	33.4/Jan	6.77	2.28	7.28	5.04	21.37

Source: WRCC, 2003
N.P. = National Park
[1] Average temperature for period of record shown; average precipitation from 1971-2000

B. Evaporation Pan:

Station Name	Elevation (in feet)	Period of Record Used for Averages	Avg. Annual Evap (in inches)
Grand Canyon N P. 2	6,790	1976 - 2002	44.04

Source: WRCC, 2003

C. AZMET:

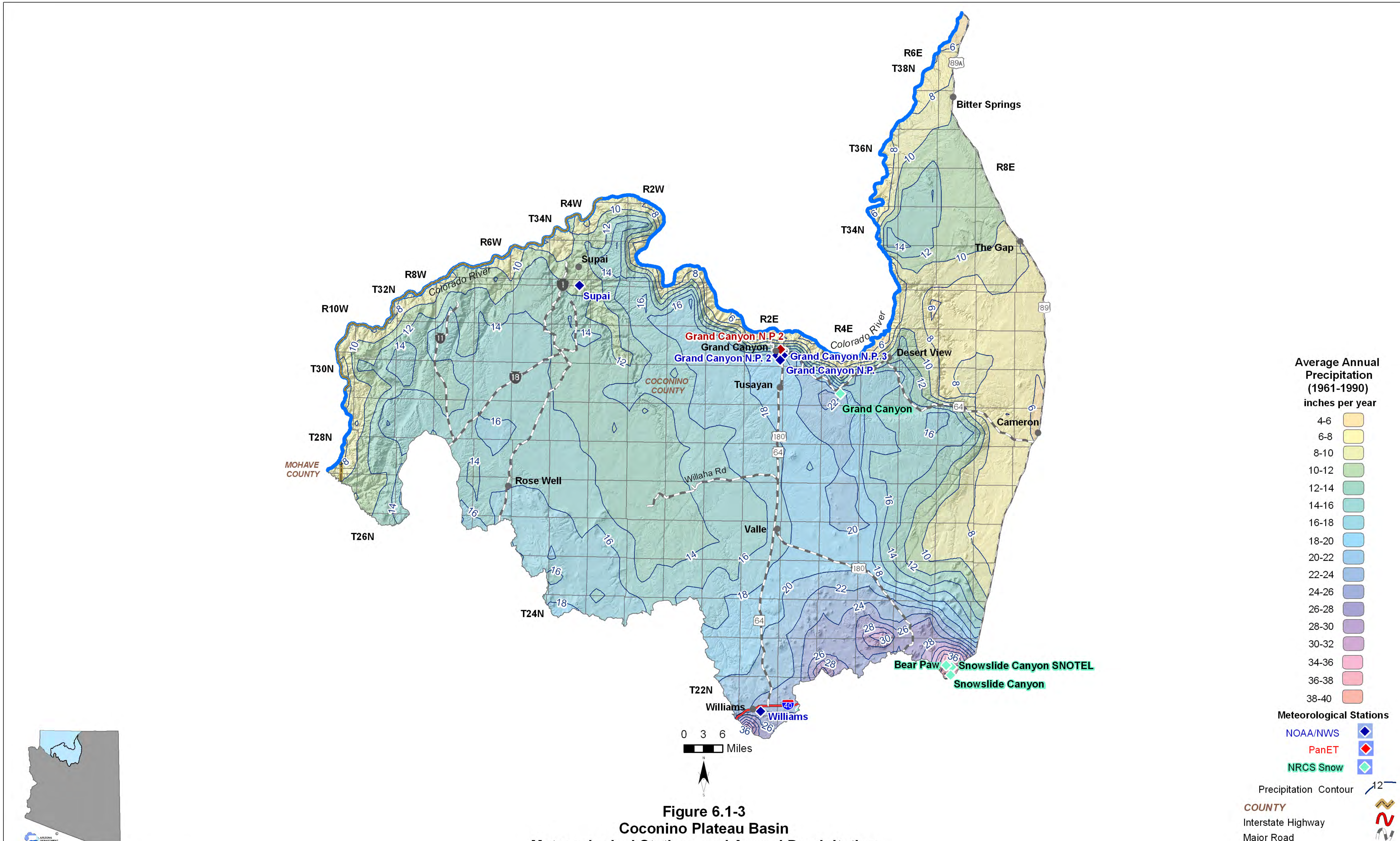
Station Name	Elevation (in feet)	Period of Record Used for Averages	Average Annual Reference Evaportranspiration, in inches (*Number of years to calculate averages*)
None			

Source: Arizona Meteorological Network, 2005

D. SNOTEL/Snowcourse:

Station Name	Elevation (in feet)	Period of Record Used for Averages	Average Snowpack, as Snow Water Content, at the Beginning of the Month, in Inches *(Number of measurements to calculate average)*					
			Jan.	Feb.	March	April	May	June
Bear Paw	10,100	1968 - current	9.8*(16)*	11.7*(27)*	17.8*(36)*	20.8*(37)*	18.1*(20)*	7.1*(11)*
Grand Canyon	7,500	1947 - current	1.2*(22)*	2.3*(56)*	2.1*(57)*	0.7*(54)*	0*(0)*	0*(0)*
Snowslide Canyon	9,750	1968 - current	6.7*(16)*	9.0*(27)*	13.4*(36)*	15.2*(37)*	9.1*(20)*	0.7*(10)*
Snowslide Canyon (SNOTEL)	9,730	1998 - current	*6.3(7)*	*8.4(7)*	*12.6(7)*	*14.0(7)*	*8.7(7)*	0*(7)*

Source: NRCS, 2005



Precipitation Data Source: Oregon State University, 1998

Figure 6.1-3
Coconino Plateau Basin
Meteorological Stations and Annual Precipitation

6.1.4 Surface Water Conditions in the Coconino Plateau Basin

Streamflow data, including average seasonal flow, average annual flow and other information are shown in Table 6.1-2. Flood ALERT equipment in the basin is shown in Table 6.1-3. Reservoir and stockpond data, including maximum storage or maximum surface area, are shown in Table 6.1-4. The location of streamflow gages identified by USGS number, flood ALERT equipment, USGS runoff contours and large reservoirs are shown on Figure 6.1-5. A description of stream data sources and methods is found in Volume 1, Section 1.3.16. A description of reservoir data sources and methods is found in Volume 1, Section 1.3.11. A description of stockpond data sources and methods is found in Volume 1, Section 1.3.15.

Streamflow Data

- Refer to Table 6.1-2.
- Data from 12 stations located at eight watercourses are shown in the table and on Figure 6.1-5. Six of the 12 stations have been discontinued and four of the six remaining stations are real-time stations.
- Average seasonal flow is relatively similar in all seasons at most stations due to regulated flow on the Colorado River or proximity to springs. Notable exceptions are, Moenkopi Wash near Cameron and Bright Angel Creek near Grand Canyon. Moenkopi Wash reports highest seasonal flow in the summer (July-September) when 78% of the average annual flow occurs and Bright Angel Creek receives highest seasonal flow in the spring (April-June) when 50% of the average annual flow occurs.
- The largest annual flow recorded in the basin is 15.97 million acre feet in 1997 at the Colorado River above Diamond Creek near Peach Springs station with a contributing drainage area of 144,660 square miles.
- All eight streams in this basin have a mean and median annual flow of over 10,000 acre-feet. Two of those eight streams, Little Colorado River and the Colorado River, have a mean annual flow of over 100,000 acre-feet.
- The main tributary to the Colorado River, the Little Colorado River has a mean annual flow of 162,000 acre-feet near Cameron. As shown on Figure 6.1-4, there is significant variability in year to year flow.

Flood ALERT Equipment

- Refer to Table 6.1-3.
- As of October 2005 there were two stations in the basin, one is a precipitation/ stage station and the other is a repeater/precipitation station.

Reservoirs and Stockponds

- Refer to Table 6.1-4.
- The basin contains 12 large reservoirs. The largest is Dogtown with a maximum storage capacity of 1,390 acre-feet.
- The most common use of the large reservoirs is for fire protection or as a stock or farm pond. Dogtown, Kaibab and Cataract Reservoirs provide water supply for the City of Williams.
- Most large reservoirs with a 50-acre surface area or greater in this basin are either dry or

intermittent lakes.

- Surface water is stored or could be stored in 45 small reservoirs in the basin.
- There are 757 registered stockponds in this basin.

Runoff Contour

- Refer to Figure 6.1-5.
- Average annual runoff is highest, two inches per year or 106 acre-feet per square mile, in the southeastern portion of the basin and decreases to 0.1 inches, or five acre-feet per square mile, along most of the Colorado River.

Figure 6.1-4 Annual flows (acre-feet) at Little Colorado River near Cameron, water years 1948-2006 (Station #9402000)

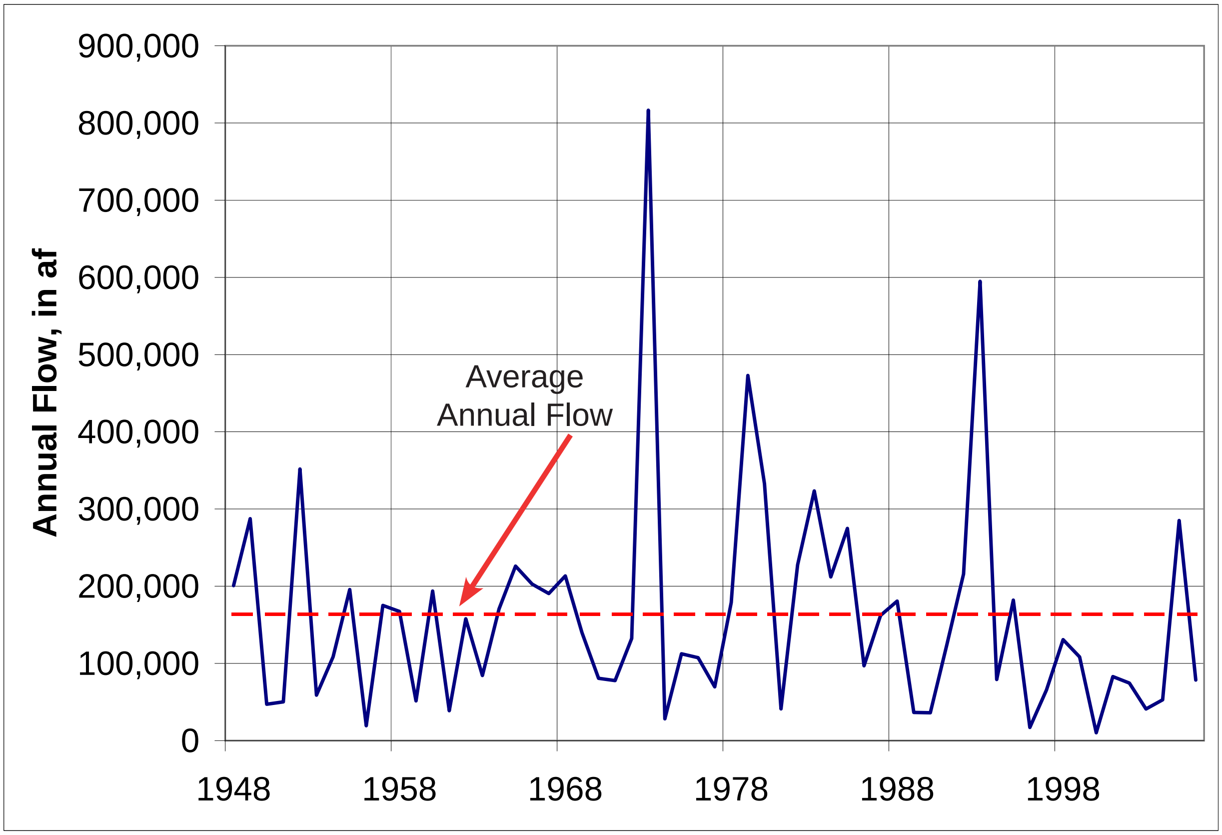


Table 6.1-2 Streamflow Data for the Coconino Plateau Basin

Station Number	USGS Station Name	Drainage Area (in mi^2)	Mean Basin Elevation (in feet)	Period of Record	Average Seasonal Flow (% of annual flow)				Annual Flow/Year (in acre-feet)				Years of Record
					Winter	Spring	Summer	Fall	Minimum	Median	Mean	Maximum	
9401500	Moenkopi Wash near Cameron	2,662	NA	10/1953-1/1965 (discontinued)	6	3	78	13	3,671 (1960)	6,936	9,981	19,909 (1963)	11
9402000	Little Colorado River near Cameron	26,091	6,300	6/1947-current (real time)	34	26	27	14	10,215 (2000)	138,315	162,519	816,449 (1973)	55
9402300	Little Colorado River above the mouth near Desert View	26,578	NA	5/1990 - current (real time)	No statistics run; less than 3 years of data								
9402450	Cottonwood Spring above confluence with Cottonwood Creek near Grand Canyon	NA	NA	10/1994-1/2003 (discontinued)	No statistics run; less than 3 years of data								
9403000	Bright Angel Creek near Grand Canyon	101	7,390	10/1923-4/1993 (discontinued)	18	50	16	16	11,366 (1972)	21,502	25,165	65,737 (1941)	51
9403043	Hermit Creek above Tonto Trail near Grand Canyon	NA	NA	10/1994-1/2003 (discontinued)	No statistics run; less than 3 years of data								
9404110	Havasu Creek at Supai	2,600	NA	9/1995-current	25	25	26	24	46,985 (1996)	47,421	47,514	47,930 (1998)	7
9404112	Havasu Creek above Havasu Falls near Supai	2,898	NA	9/1995-6/2000 (discontinued)	25	24	27	25	39,022 (1996)	39,964	40,090	41,412 (1998)	4
9404115	Havasu Creek above the mouth near Supai	2,811	NA	11/1990-current	25	24	27	24	50,474 (2002)	52,176	52,574	55,471 (1992)	4
9404120	Colorado River above National Canyon near Supai	143,279	NA	7/1983-4/1996 (discontinued)	24	22	32	22	8,246,104 (1990)	8,542,935	8,526,042	8,789,087 (1991)	3
9404200	Colorado River above Diamond Creek near Peach Springs	144,660	NA	8/1983-current (real time)	25	25	28	23	8,450,947 (2002)	9,254,765	10,426,177	15,974,970 (1997)	13
9404208	Diamond Creek near Peach Springs	280	NA	5/1993-current (real time)	29	18	31	22	2,209 (2002)	2,629	2,967	5,026 (1999)	9

Sources: USGS NWIS, USGS 1998 and USGS 2003.

Notes:
NA = Not available
Statistics based on Calendar Year
Annual Flow statistics based on monthly values
Annual Flow/Year statistics were only completed for those gages that had at least 3year of 12 month records.
Summation of Average Annual Flows may not equal 100 due to rounding.
Period of record may not equal Year of Record used for annual Flow/Year statistics due to only using years with a 12 month record

Table 6.1-3 Flood ALERT Equipment in the Coconino Basin

Station ID	Station Name	Station Type	Install Date	Responsibility
3920	City Dam in Williams	Precipitation/Stage	9/23/2005	ADWR
7540	Manzanita Repeater	Repeater/Precipitation	NA	Mohave County FCD

Notes:
ADWR = Arizona Department of Water Resources
FCD = Flood Control District
NA = Information is not available at this time

Table 6.1-4 Reservoirs and Stockponds in the Coconino Plateau Basin

A. Large Reservoirs (500 acre-feet capacity and greater)

MAP KEY	RESERVOIR/LAKE NAME *(Name of dam, if different)*	OWNER/OPERATOR	MAXIMUM STORAGE (AF)	USE[1]	JURISDICTION
1	Dogtown	City of Williams	1,390	F,R,S	State
2	Kaibab	City of Williams	967	F,R,S	State
3	Long Point	AZ Land Dept/ Babbitt Ranches	946[2]	P	State
4	Cataract *(West Cataract Creek)*	City of Williams	860[2]	R,S	State
5	Gonzales[3,5]	Private	776	O	Landowner

Source: U.S. Army Corps of Engineers 2005, City of Williams 2007

B. Other Large Reservoirs (50 acre surface area or greater)[4]

MAP KEY	RESERVOIR/LAKE NAME *(Name of dam, if different)*	OWNER/OPERATOR	MAXIMUM SURFACE AREA (acres)	USE[1]	JURISDICTION
6	Davenport	Kaibab NF	252	P	Federal
7	Red Lake Tank[5]	Kaibab NF	200	P	Federal
8	Dog Knob[6]	Kaibab NF	178	P	Federal
9	Stone[5]	Kaibab NF	153	P	Federal
10	Tule[6]	Havasupai Tribe	108	P	Tribal
11	Laguna[5]	Hualapai Tribe	89	P	Tribal
12	Smoot	Private	50	P	Landowner

C. Small Reservoirs (greater than 15 acre-feet and less than 500 acre-feet capacity)

Total number: 8
Total maximum storage: 892 acre-feet

D. Other Small Reservoirs (between 5 and 50 acres surface area)[3]

Total number: 37
Total surface area: 521 acres

E. Stockponds (up to 15 acre-feet capacity)

Total number: 757

[1] F=fish & wildlife pond; O=Other; P=fire protection, stock or farm pond; R=recreation; S=water supply
[2] Normal capacity < 500acre-feet
[3] The height of this dam is less than 6 feet. It is not regulated by State or Federal government.
[4] Capacity data not available to ADWR
[5] Intermittent lake
[6] Dry

Figure 6.1-5
Coconino Plateau Basin
Surface Water Conditions

6.1.5 Perennial/Intermittent Streams and Major Springs in the Coconino Plateau Basin

Major and minor springs with discharge rates and date of measurement, and the total number of springs in the basin are shown in Table 6.1-5. The locations of major springs and perennial and intermittent streams are shown on Figure 6.1-6. A description of data sources and methods for intermittent and perennial reaches is found in Volume 1, Section 1.3.16. A description of spring data sources and methods is found in Volume 1, Section 1.3.14.

- Numerous perennial streams are located along and in the vicinity of the northern basin boundary. All perennial reaches, aside from the Colorado River, are short, spring fed and flow into the Colorado River.
- Intermittent streams are found along the Colorado River and in the vicinity of Williams. The Little Colorado River is intermittent for most of its length in the basin.
- There are 28 major springs with a measured discharge of 10 gallons per minute (gpm) or greater at any time.
- Listed discharge rates may not be indicative of current conditions. Many of the measurements were taken during or prior to 1994.
- Most springs are located along the Colorado River. The greatest discharge rate, 101,600 gpm, was measured at the Blue springs area which support perennial flow in the Little Colorado River.
- Springs with measured discharge of 1 to 10 gpm are not mapped but coordinates are given in Table 6.1-5B. There are 27 minor springs in this basin.
- The total number of springs, regardless of discharge, identified by the USGS varies from 71 to 80, depending on the database reference.

Table 6.1-5 Springs in the Coconino Plateau Basin

A. Major Springs (10 gpm or greater):

Map Key	Name	Location		Discharge (in gpm)[1]	Date Discharge Measured
		Latitude	Longitude		
1	Blue-springs area[2]	360700	1114137	101,600	1950-1993
2	Havasu	361303	1124112	28,500	8/23/1994
3	Artesian at River Mile 182	361025	1130711	2,230	5/28/1995
4	Hawaii	360414	1121305	398	4/11/2001
5	Warm (multiple)	361148	1130459	390	5/28/1995
6	Hermit Creek	360417	1121307	328	11/21/2002
7	Diamond	354248	1131538	251	5/19/1993
8	Diamond Creek	354311	1131352	244	6/9/1994
9	Unnamed[3,4]	361627	1124331	200	5/20/1950
10	Hance at campground[3]	360106	1115732	179	4/8/2001
11	Three Springs[3]	355308	1131829	170	3/24/2004
12	Blue Mountain Canyon[3]	354302	1131747	100	6/9/1994
13	Unnamed[3,4]	361535	1124226	100	5/20/1950
14	Beecher	360957	1130802	90	5/28/1995
15	West Elk	352248	1115917	70	6/6/1979
16	Granite Spring Canyon[3]	354855	1131833	57[5]	5/19/1993
17	Matkatamiba	362032	1124017	54	11/10/2003
18	East Elk	352236	1115912	47	6/6/1979
19	Garden Creek below Tonto Trail	360440	1120740	45	11/9/2000
20	National Canyon (total flow)	361518	1125239	33	10/21/1997
21	Colorado River Mile 140[3]	362338	1123516	25[6]	6/22/1950
22	Newman	352418	1115149	20	6/5/1979
23	Monument[3]	360356	1121032	18	11/21/2002
24	Unnamed	362837	1115042	15	4/29/1976
25	Granite Park[3]	355750	1131836	14	10/13/1993
26	Monument Creek[3]	360455	1121110	13	8/23/2003
27	Pipe Creek	360409	1120557	12[5]	12/7/2000
28	Unnamed[2,3]	361627	1124226	10	5/20/1950

Table 6.1-5 Springs in the Coconino Plateau Basin (cont'd.)

B. Minor Springs (1 to 10 gpm):

Name	Location		Discharge (in gpm)[1]	Date Discharge Measured
	Latitude	Longitude		
Fern	361524	1124204	8	8/24/1994
Boucher east	360609	1121414	8	4/12/2001
Tappen	355129	1112633	8	9/26/2001
Royal Arch	361119	1122715	7	3/23/2002
Mohawk Canyon	361246	1125815	5	5/19/2002
Cottonwood	360128	1115912	5	11/29/2000
Miner's	360059	1115817	5[7]	11/20/1981
Burro	360436	1120604	4	4/8/2001
Honga above mouth	361237	1130257	4[7]	10/10/1993
Pipe	360415	1120606	4	5/22/2000
Raspberry	352030	1113852	4	8/30/1978
222 Mile Canyon	354815	1131920	3	5/31/1995
Big	355959	1131227	3	5/20/1993
Unnamed	355502	1131959	2	10/13/1993
Unnamed	355502	1131959	2	5/31/1995
Red Canyon	360020	1115604	2	6/3/2002
Pumphouse	360440	1120731	2[7]	11/19/2001
Grapevine East	360232	1120042	2[7]	11/29/2000
Grapevine Main	360039	1120009	1	11/15/2001
Forester Canyon 2	361403	1123142	1	1/20/2002
National Canyon	361346	1125215	1	11/6/2002
Salt Creek	360436	1120940	1	4/1/2001
Clover	351351	1121211	1	8/5/1976
Sapphire	360711	1121846	1	10/23/2003
Horn	360450	1120836	1	11/22/2002
Hockey Puck	355602	1131032	1	6/9/1994
Unnamed[3,4]	351509	113524	1	11/1950

C. Total number of springs, regardless of discharge, identified by USGS (see ALRIS, 2005 and NHD, 2006): 71 to 80

Notes:

[1] Most recent measurement identified by ADWR
[2] Discharge is average for all springs in the lower 13 mile reach of the Little Colorado River, date measured varies by spring
[3] Spring is not displayed on current USGS topo maps
[4] Location approximated by ADWR
[5] Spring flow is highly variable. Earlier measurement is shown, most recent measurement < 10gpm
[6] Average discharge
[7] Spring flow is highly variable. Earlier measurement is shown, most recent measurement < 1gpm

Figure 6.1-6
Coconino Plateau Basin
Perennial\Intermittent Streams
and Major (>10 gpm) Springs

6.1.6 Groundwater Conditions of the Coconino Plateau Basin

Major aquifers, well yields, estimated water in storage, number of index wells and date of last water-level sweep are shown in Table 6.1-6. Figure 6.1-7 shows aquifer flow direction and water-level change between 1990-1991 and 2003-2004. Figure 6.1-8 contains hydrographs for selected wells shown on Figure 6.1-7. Figure 6.1-9 shows well yields in four yield categories. A description of aquifer data sources and methods is found in Volume 1, Section 1.3.2. A description of well data sources and methods, including water-level changes and well yields, is found in Volume 1, Section 1.3.19.

Major Aquifers

- Refer to Table 6.1-6 and Figure 6.1-7.
- Major aquifers in the basin include volcanic rocks, basin fill and sedimentary rocks (C- and R-aquifers and Moenkopi and Chinle Formations).
- Almost all of the basin geology consists of consolidated crystalline and sedimentary rock.
- Flow direction is toward the Little Colorado River in the eastern portion of the basin and generally toward the west in the western portion of the basin.

Well Yields

- Refer to Table 6.1-6 and Figure 6.1-9.
- As shown on Figure 6.1-9, well yields in this basin are generally less than 100 gallons per minute (gpm). However, there are several relatively high yield wells owned by the City of Flagstaff in the southeast part of the basin.
- One source of well yield information, based on 16 reported wells, indicates that the median well yield in this basin is 45.5 gpm.

Water Level

- Refer to Figure 6.1-7. Water levels are shown for wells measured in 2003-2004.
- The Department annually measures two index wells in this basin (see Figure 6.1-8, hydrographs B and C).
- All water level information is from the southern portion of the basin. The deepest water level shown on the map is 2,518 feet at Tusayan. Although not shown on the map, there are three wells with a depth to water of over 2,700 feet in the vicinity of Williams. The shallowest water level shown on the map is three feet in a perched aquifer south of Williams.
- Hydrographs corresponding to selected wells shown on Figure 6.1-7 but covering a longer time period are shown in Figure 6.1-8.

Table 6.1-6 Groundwater Data for the Coconino Plateau Basin

Basin Area, in square miles:	5,812	
Major Aquifer(s):	**Name and/or Geologic Units**	
	Volcanic Rock	
	Basin Fill	
	Sedimentary Rock (Moenkopi and Chinle Formations)	
	Sedimentary Rock (C Aquifer)	
	Sedimentary Rock (R Aquifer)	
Well Yields, in gal/min:	44 (1 well measured)	Measured by ADWR and/or USGS
	Range 4-1,500 Median 45.5 (16 reported)	Reported on registration forms for large (> 10-inch) diameter wells
	Range 30-100	ADWR (1990)
	Range 0-10	USGS (1994)
Estimated Natural Recharge, in acre-feet/year:	N/A	
Estimated Water Currently in Storage, in acre-feet:	3,000,000*	Montgomery et al, 2000
	N/A	Arizona Water Commission (1975)
Current Number of Index Wells:	2	
Date of Last Water-level Sweep:	1964 (5 wells measured)	

* Estimated by ADWR based on the assumptions by Montgomery et al (2000) of an average specific yield (drainage porosity) of 0.1%. Montgomery at al's study area was larger than and covered most of the Coconino Plateau Basin.
N/A = Not Available

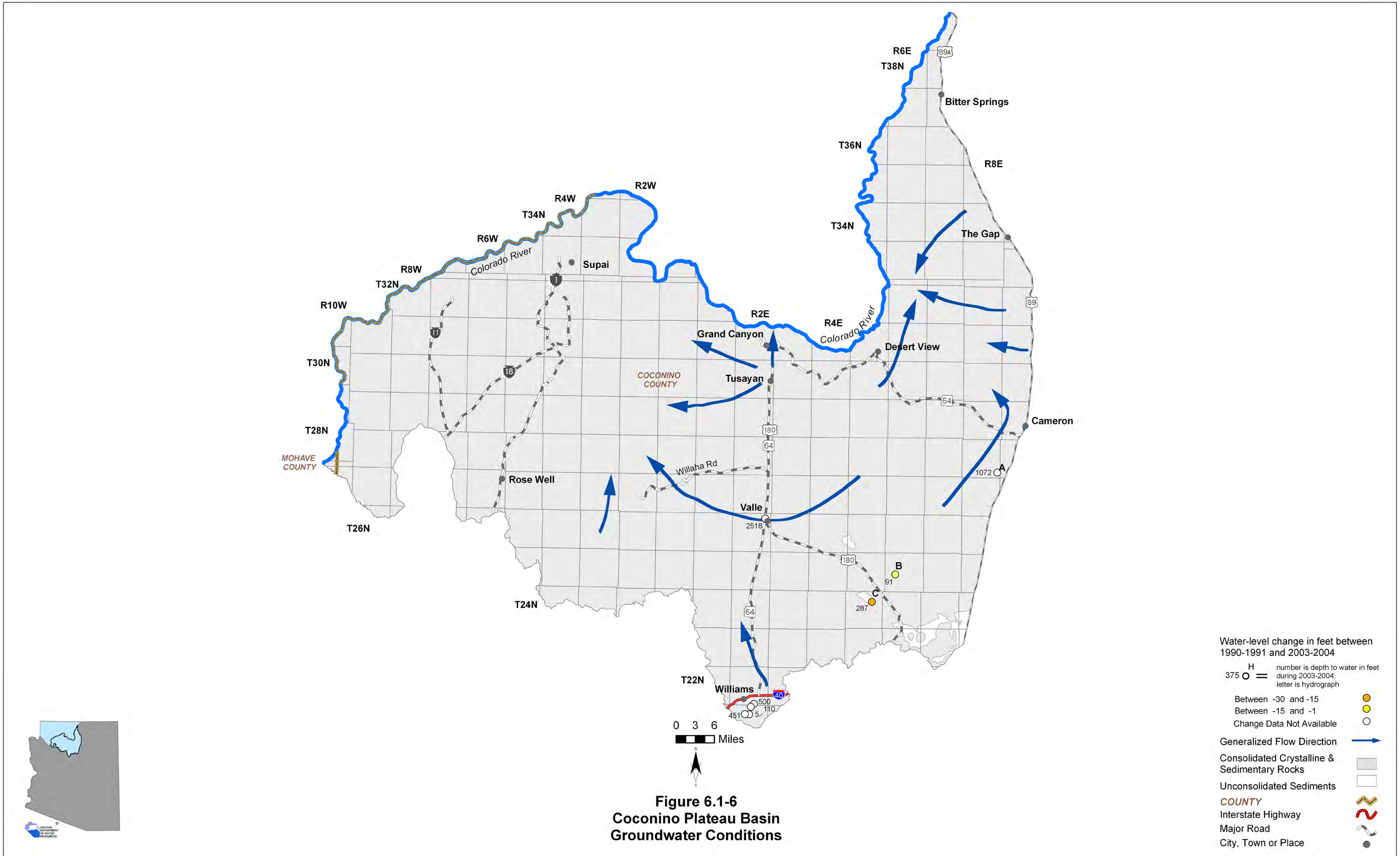


Figure 6.1-6
Coconino Plateau Basin
Groundwater Conditions

Figure 6.1-8
Coconino Plateau
Hydrographs Showing Depth to Water in Selected Wells

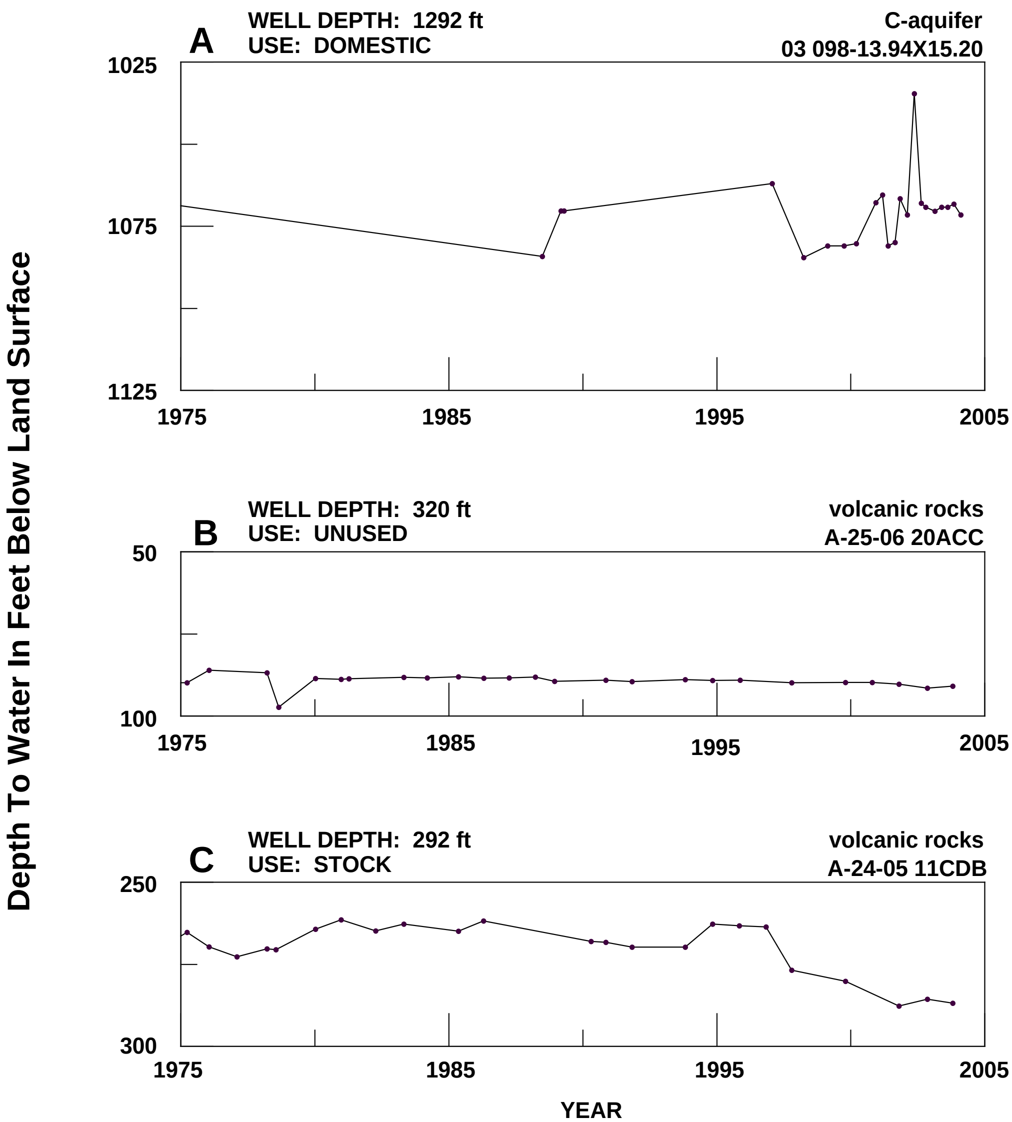


Figure 6.1-9
Coconino Plateau Basin
Well Yields

6.1.7 Water Quality of the Coconino Plateau Basin

Wells, springs and mine sites with parameter concentrations that have equaled or exceeded drinking water standard(s), including location and parameter(s) are shown in Table 6.1-7A. Impaired lakes and streams with site type, name, length of impaired reach, area of impaired lake, designated use standard and parameter(s) exceeded is shown in Table 6.1-7B. Figure 6.1-10 shows the location of water quality occurrences keyed to Table 6.1-7. A description of water quality data sources and methods is found in Volume 1, Section 1.3.18. Not all parameters were measured at all sites; selective sampling for particular constituents is common.

Wells, Springs and Mines

- Refer to Table 6.1-7A.
- Twenty-two wells or springs have parameter concentrations that have equaled or exceeded drinking water standards.
- The parameter most frequently equaled or exceeded in the sites measured was arsenic.
- Other parameters equaled or exceeded include total dissolved solids, radionuclides, thallium, nitrates, mercury and lead.

Lakes and Streams

- Refer to Table 6.1-7B.
- The water quality standard for suspended sediment concentration was exceeded in one 28-mile stream reach, the Colorado River from Parashant Canyon to Diamond Creek. This impaired reach also forms part of the border with the Shivwits Plateau Basin.
- This reach is not part of the ADEQ water quality improvement effort called the Total Maximum Daily Load (TMDL) Program at this time.

Effluent Dependent Reaches

- See Figure 6.1-10
- There is one effluent dependent reach in this basin, which receives effluent from the South Rim Wastewater Treatment Plant.

Table 6.1-7 Water Quality Exceedences in the Coconino Plateau Basin[1]

A. Wells, Springs and Mines

Map Key	Site Type	Site Location			Parameter(s) Concentration has Equaled or Exceeded Drinking Water Standard (DWS)[2]
		Township	Range	Section	
1	Spring	33 North	5 East	NA	TDS
2	Spring	32 North	7 East	31	TDS
3	Spring	31 North	2 East	15	Rad
4	Well	31 North	9 East	33	Tl
5	Spring	30 North	4 East	4	As
6	Spring	29 North	9 East	15	NO3
7	Well	25 North	2 East	27	TDS
8	Spring	33 North	4 West	11	Pb
9	Well	33 North	4 West	22	As
10	Spring	33 North	4 West	35	As, Pb
11	Spring	33 North	7 West	31	As
12	Spring	33 North	8 West	36	As, Hg
13	Spring	33 North	8 West	36	As, Hg
14	Spring	32 North	8 West	22	As
15	Spring	30 North	10 West	25	As
16	Spring	29 North	9 West	19	As
17	Spring	29 North	10 West	14	As, TDS
18	Spring	29 North	10 West	14	As
19	Spring	29 North	10 West	25	As
20	Well	27 North	6 West	12	Pb
21	Spring	27 North	9 West	15	As
22	Spring	27 North	10 West	24	As

B. Lakes and Streams

Map Key	Site Type	Site Name	Length of Impaired Stream Reach (in miles)	Area of Impaired Lake (in acres)	Designated Use Standard[3]	Parameter(s) Exceeding Use Standard[2]
a	Stream	Colorado River (Parashant Canyon to Diamond Creek)	284	NA	A&W	SSC

Notes:

NA = Not Applicable
[1] Water quality samples collected between 1951 and 1994.
[2]As = Arsenic
Pb = Lead
Hg = Mercury
NO3 = Nitrate/nitrite
Rad = One or more of the following radionuclides - Gross Alpha, Gross Beta, Radium, and Uranium
Tl = Thallium
TDS = Total Dissolved Solids
SSC = Suspended Sediment Concentration
[3] A&W = aquatic and wildlife
[4] Total length of the impaired reach. This reach forms a portion of the border with the Shivwits Plateau Basin.

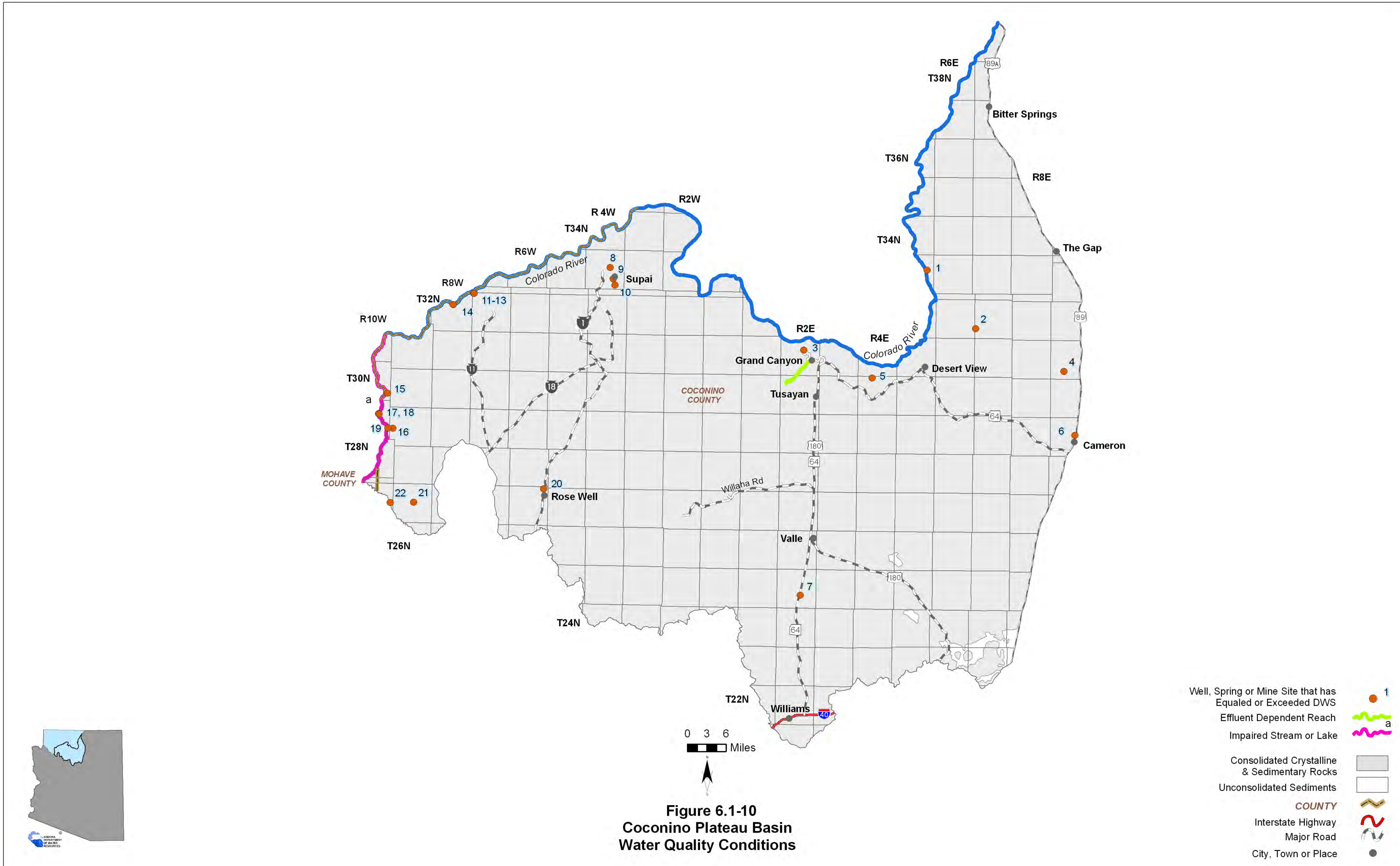


Figure 6.1-10
Coconino Plateau Basin
Water Quality Conditions

6.1.8 Cultural Water Demands in the Coconino Plateau Basin

Cultural water demand data including population, number of wells and the average well pumpage and surface water diversions by the municipal, industrial and agricultural sectors are shown in Table 6.1-8. Effluent generation including facility ownership, location, population served and not served, volume treated, disposal method and treatment level is shown in Table 6.1-9. Figure 6.1-11 shows the location of demand centers. A description of cultural water demand data sources and methods is found in Volume 1, Section 1.3.5. More detailed information on cultural water demands is found in Section 5.0.7.

Cultural Water Demands

- Refer to Table 6.1-8 and Figure 6.1-11.
- Population in this basin increased from 6,977 in 1980 to 9,164 in 2000 and is projected to reach 16,589 by 2050. This is the most populous basin in the planning area.
- All cultural water use in this basin is for municipal demand. Municipal demand centers include Williams, Tusayan, Grand Canyon Village, Valle, Supai and Cameron.
- Groundwater demand is small and has remained relatively constant from 1971-2003. In 2000 the City of Williams started using groundwater because surface water supplies were unavailable due to drought. Groundwater use increased to 344 acre-feet in 2003.
- Data on municipal surface water use prior to 1991 is not available. From 1991-2003 municipal surface water use decreased from 500 acre-feet per year to 350 acre-feet per year due to surface water shortages in Williams.
- As of 2003 there were 152 registered wells with a pumping capacity of less than or equal to 35 gallons per minute and 17 wells with a pumping capacity of more than 35 gallons per minute.

Effluent Generation

- Refer to Table 6.1-9.
- There are eight wastewater treatment facilities in this basin.
- Information on population served was available for two facilities and information on effluent generation was available for five facilities. These facilities serve almost 3,700 people and generate over 1,800 acre-feet of effluent per year.
- Three facilities discharge to watercourses, two discharge to an evaporation pond, four discharge for irrigation, one discharges to a golf course, two discharge for municipal uses such as toilet flushing and one discharges to an unlined impoundments that recharge the aquifer.

Table 6.1-8 Cultural Water Demands in the Coconino Plateau Basin[1]

<table>
<tr><th rowspan="3">Year</th><th rowspan="3">Recent (Census) and Projected (DES) Population</th><th colspan="2" rowspan="2">Number of Registered Water Supply Wells Drilled</th><th colspan="7">Average Annual Demand (in acre-feet)</th></tr>
<tr><th colspan="3">Well Pumpage</th><th colspan="3">Surface-Water Diversions</th><th rowspan="2">Data Source</th></tr>
<tr><th>Q ≤ 35 gpm</th><th>Q > 35 gpm</th><th>Municipal</th><th>Industrial</th><th>Irrigation</th><th>Municipal</th><th>Industrial</th><th>Irrigation</th></tr>
<tr><td>1971</td><td></td><td rowspan="10">101[2]</td><td rowspan="10">10[2]</td><td colspan="3" rowspan="5"><500</td><td colspan="3" rowspan="5">NR</td><td rowspan="20">ADWR (1994)</td></tr>
<tr><td>1972</td><td></td></tr>
<tr><td>1973</td><td></td></tr>
<tr><td>1974</td><td></td></tr>
<tr><td>1975</td><td></td></tr>
<tr><td>1976</td><td></td><td colspan="3" rowspan="5"><500</td><td colspan="3" rowspan="5">NR</td></tr>
<tr><td>1977</td><td></td></tr>
<tr><td>1978</td><td></td></tr>
<tr><td>1979</td><td></td></tr>
<tr><td>1980</td><td>6,977</td></tr>
<tr><td>1981</td><td>7,051</td><td rowspan="5">9</td><td rowspan="5">0</td><td colspan="3" rowspan="5"><500</td><td colspan="3" rowspan="5">NR</td></tr>
<tr><td>1982</td><td>7,126</td></tr>
<tr><td>1983</td><td>7,200</td></tr>
<tr><td>1984</td><td>7,275</td></tr>
<tr><td>1985</td><td>7,349</td></tr>
<tr><td>1986</td><td>7,424</td><td rowspan="5">19</td><td rowspan="5">3</td><td colspan="3" rowspan="5"><500</td><td colspan="3" rowspan="5">NR</td></tr>
<tr><td>1987</td><td>7,498</td></tr>
<tr><td>1988</td><td>7,573</td></tr>
<tr><td>1989</td><td>7,647</td></tr>
<tr><td>1990</td><td>7,722</td></tr>
<tr><td>1991</td><td>7,866</td><td rowspan="5">15</td><td rowspan="5">3</td><td rowspan="5"><300</td><td rowspan="5">NR</td><td rowspan="5">NR</td><td rowspan="5">500</td><td rowspan="5">NR</td><td rowspan="5">NR</td><td rowspan="13">USGS (2005) ADWR (2005)</td></tr>
<tr><td>1992</td><td>8,010</td></tr>
<tr><td>1993</td><td>8,155</td></tr>
<tr><td>1994</td><td>8,299</td></tr>
<tr><td>1995</td><td>8,443</td></tr>
<tr><td>1996</td><td>8,587</td><td rowspan="5">2</td><td rowspan="5">0</td><td rowspan="5"><300</td><td rowspan="5">NR</td><td rowspan="5">NR</td><td rowspan="5">600</td><td rowspan="5">NR</td><td rowspan="5">NR</td></tr>
<tr><td>1997</td><td>8,731</td></tr>
<tr><td>1998</td><td>8,876</td></tr>
<tr><td>1999</td><td>9,020</td></tr>
<tr><td>2000</td><td>9,164</td></tr>
<tr><td>2001</td><td>9,282</td><td rowspan="3">6</td><td rowspan="3">1</td><td rowspan="3">300</td><td rowspan="3">NR</td><td rowspan="3">NR</td><td rowspan="3">350</td><td rowspan="3">NR</td><td rowspan="3">NR</td></tr>
<tr><td>2002</td><td>9,401</td></tr>
<tr><td>2003</td><td>9,519</td></tr>
<tr><td>2010</td><td>10,346</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>2020</td><td>11,793</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>2030</td><td>13,187</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>2040</td><td>14,753</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>2050</td><td>16,589</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="2">ADDITIONAL WELLS:[3]</td><td>10</td><td></td><td colspan="7"></td></tr>
<tr><td colspan="2">WELL TOTALS:</td><td>152</td><td>17</td><td colspan="7"></td></tr>
</table>

[1] Does not include evaporation losses from stockponds and reservoirs.
[2] Includes all wells through 1980.
[3] Other water-supply wells are listed in the ADWR Well Registry for this basin, but they do not have completion dates. These wells are summed here.
NR - Not reported
Note: Surface water diverted in the Kanab Plateau Basin is delivered to the Coconino Plateau Basin for use at the Grand Canyon South Rim. This diversion is not included in the table.

Table 6.1-9 Effluent Generation in the Coconino Plateau Basin

Facility Name	Ownership	City/Location Served	Population Served	Volume Treated/Generated (acre-feet)	Disposal Method								Current Treatment Level	Population Not Served	Year of Record
					Water-course	Evaporation Pond	Irrigation	Golf Course	Municipal Reuse	Wildlife Area	Discharged to Another Facility	Infiltration Basins			
Cameron WWTP	Navajo Tribe	Cameron	NA	NA		X							NA		2004
Desert View WWTP	National Park Service	Campground	NA	11		Lagoon							NA		2004
Grand Canyon Inn	Private	Hotel	NA	NA			X						NA		
Grand Canyon Valle Airport WWTP	Private	Valle	NA	NA			X						NA		
South Rim WWTP	National Park Service	Park	NA	448	Bright Angel Wash		X		X				Tertiary	NA	2004
Supai Village Sewer System	Havasupai Tribe	Supai	1,000	56								X	Secondary	NA	2001
Tusayan WWTP	South Grand Canyon Sanitary District	Tusayan	NA	68	Coconino Wash		X		X						2004
Williams WWTP	Williams	Williams	2,690	1,138	Cataract Creek			Elephant Rock					Secondary	NA	2000
Total			3,690	1,721											

NA: Data not currently available to ADWR
WWTP: Waste Water Treatment Plant

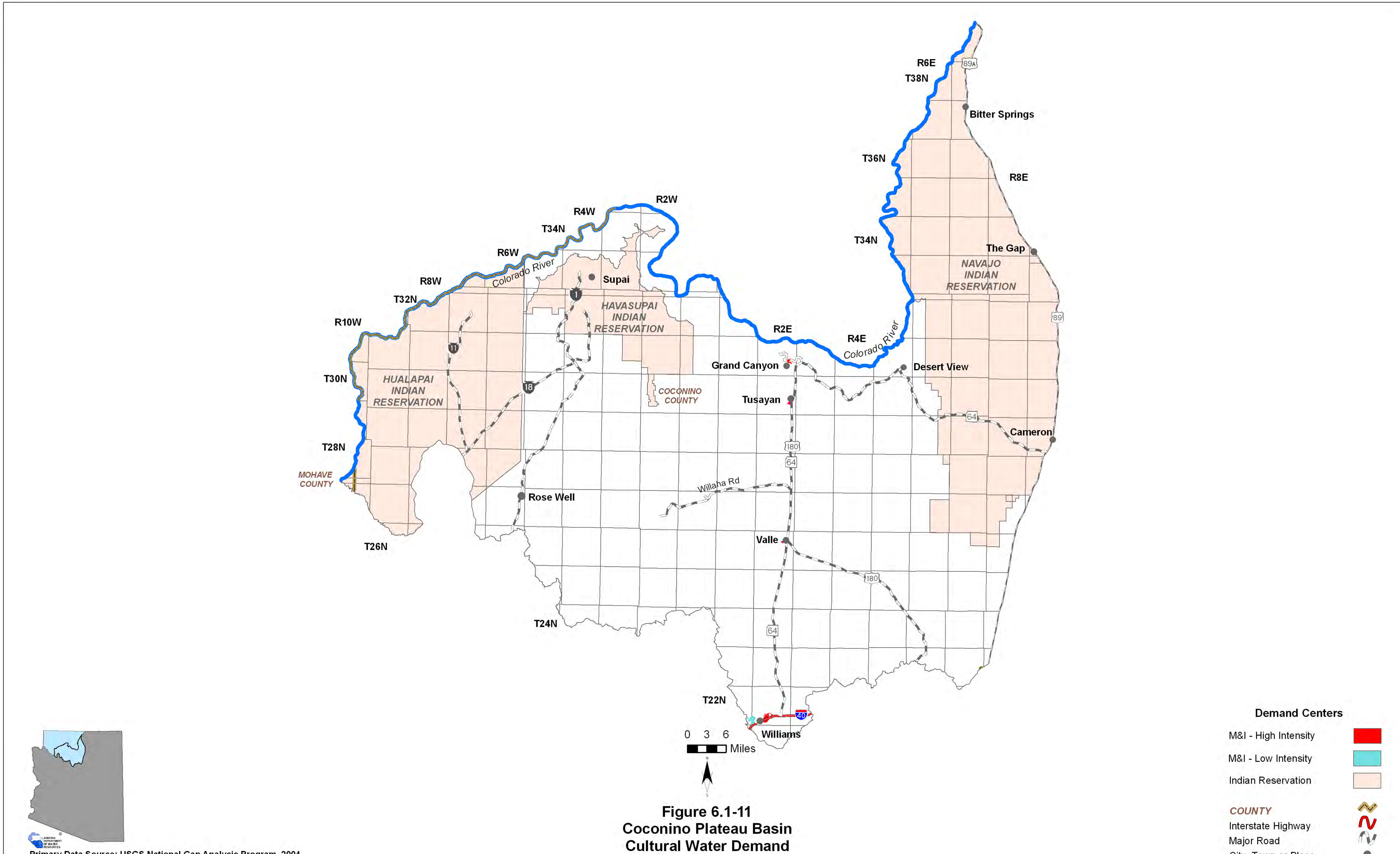


Figure 6.1-11
Coconino Plateau Basin
Cultural Water Demand

6.1.9 Water Adequacy Determinations in the Coconino Plateau Basin

Water adequacy determination information including the subdivision name, location, number of lots, adequacy determination, reason for the inadequacy determination, date of determination and subdivision water provider are shown in Table 6.1-10. Figure 6.1-12 shows the locations of subdivisions keyed to the Table. A description of the Water Adequacy Program is found in Volume 1, Appendix A. Adequacy determination data sources and methods are found in Volume 1, Sections 1.3.1.

Water Adequacy Reports

- See Table 6.1-10
- All subdivisions receiving an adequacy determination are in the vicinity of Williams. Twenty-seven water adequacy determinations for 1,194 lots have been made in this basin through May, 2005, all were determinations of inadequacy.
- The most common reason for a determination of inadequacy was because the distribution system was insufficient to meet demands or the applicant proposed water hauling. The next most common reason was insufficient water supply.

Table 6.1-10 Adequacy Determinations in the Coconino Plateau Basin[1]

Map Key	Subdivision Name	County	Location			No. of Lots	ADWR File No.[2]	ADWR Adequacy Determination	Reason(s) for Inadequacy Determination[3]	Date of Determination	Water Provider at Time of Application
			Township	Range	Section						
1	Bally Mountain	Coconino	23 North	2 East	35	19		Inadequate	A3	01/14/93	Dry Lot Subdivision
2	Canyon Vista Ranch	Coconino	23 North	2 East	21	11	22-400438	Inadequate	A1, A2	12/05/00	Water Hauler
3	Chaparral Heights	Coconino	23 North	2 East	11	44		Inadequate	A2, A3	12/01/86	Dry Lot Subdivision
4	Highland Meadows at Williams # 1	Coconino	22 North	2 East	31	29	33-300384	Inadequate	A1	12/19/97	City of Williams
5	Highland Meadows at Williams # 2	Coconino	22 North	2 East	31	125	22-400042	Inadequate	A1	04/14/99	City of Williams
6	Highland Meadows at Williams # 3, Unit 1	Coconino	22 North	2 East	31	38	22-401256	Inadequate	D	04/26/04	City of Williams
7	Highland Meadows at Williams # 3, Unit 2	Coconino	22 North	2 East	31	39	22-401476	Inadequate	D	11/24/04	City of Williams
8	Howard Mesa Ranch Phase 2	Coconino	25 North	2 East	33	63	22-300584	Inadequate	A2	12/22/98	Dry Lot Subdivision
9	Howard Mesa Subdivision, Unit 2 & 3	Coconino	25 North	2 East	27, 35	75	22-400073	Inadequate	A2	05/14/99	Dry Lot Subdivision
10	Junipine Estates # 2, 3	Coconino	23 North	2 East	20	238		Inadequate	A2, A3	09/25/73	Dry Lot Subdivision
11	Kaibab Estates West	Coconino	22 North	2 East	11	9		Inadequate	A2, A3	02/03/92	Dry Lot Subdivision
12	Lake Kaibab Park	Coconino	23 North	2 East	15, 22, 23, 26	4		Inadequate	A3	04/08/91	D & D Water Company
13	Lake Kaibab Park # 1	Coconino	23 North	2 East	27, 35	14		Inadequate	A3	04/27/90	City of Williams
14	Lake Kaibab Park # 2	Coconino	23 North	2 East	27, 35	9		Inadequate	A3	04/06/94	A-1 Water Service
15	Lazy "E"	Coconino	22 North	2 East	30	NA		Inadequate	D	11/23/81	Dry Lot Subdivision
16	Lazy "E" # 2	Coconino	22 North	2 East	30, 31	18		Inadequate	A2, A3	07/03/86	Dry Lot Subdivision
17	Lazy "E" # 3	Coconino	22 North	2 East	31	39		Inadequate	A2, A3	06/18/93	Dry Lot Subdivision
18	Mason Commercial Center # 1	Coconino	22 North	2 East	28	4		Inadequate	A1, A2	08/26/93	City of Williams
19	Mi Casa	Coconino	22 North	2 East	33	5		Inadequate	A1	01/16/87	City of Williams
20	Mountain Shadows	Coconino	22 North	2 East	15, 22	14	22-400126	Inadequate	A2, A3	07/21/99	Dry Lot Subdivision
21	Pinecrest Estates	Coconino	22 North	2 East	29	51	22-300067	Inadequate	A1	11/20/95	City of Williams
22	Pinecrest Estates II	Coconino	22 North	2 East	29	84	22-400737	Inadequate	A1, A2	07/01/02	City of Williams
23	Red Lake Estates Unit I	Coconino	23 North	2 East	1	120	22-400401	Inadequate	A2, A3	10/30/00	A-1 Water Service
24	Red Lake Estates, Unit II	Coconino	23 North	2 East	1	23	22-400932	Inadequate	A2, A3	05/05/03	A-1 Water Service
25	Red Lake Mountain Ranch	Coconino	23 North	2 East	3	54		Inadequate	A3	03/21/89	Dry Lot Subdivision

Table 6.1-10 Adequacy Determinations in the Coconino Plateau Basin (cont'd)[1]

Map Key	Subdivision Name	County	Location			No. of Lots	ADWR File No.[2]	ADWR Adequacy Determination	Reason(s) for Inadequacy Determination[3]	Date of Determination	Water Provider at Time of Application
			Township	Range	Section						
26	Timber Canyon	Coconino	23 North	2 East	33	24	22-300249	Inadequate	A3	02/04/97	A-1 Water Service
27	Williams Pine Meadows Estates	Coconino	21 North	2 East	3, 4	41		Inadequate	A1	01/09/95	Dry Lot Subdivision

Notes:

[1] Each determination of the adequacy of water supplies available to a subdivision is based on the information available to ADWR and the standards of review and policies in effect at the time the determination was made. In some cases, ADWR might make a different determination if a similar application were submitted today, based on the hydrologic data and other information currently available, as well as current rules and policies.

[2] Prior to February 1995, ADWR did not assign file numbers to applications for adequacy determination.

[3] A. Physical/Continuous
1) Insufficient Data (applicant chose not to submit necessary information, and/or available hydrologic data insufficient to make determination)
2) Insufficient Supply (existing water supply unreliable or physically unavailable;for groundwater, depth-to-water exceeds criteria)
3) Insufficient Infrastructure (distribution system is insufficient to meet demands or applicant proposed water hauling)
B. Legal (applicant failed to demonstrate a legal right to use the water or failed to demonstrate the provider's legal authority to serve the subdivision)
C. Water Quality
D. Unable to locate records

NA = Not available to ADWR at this time

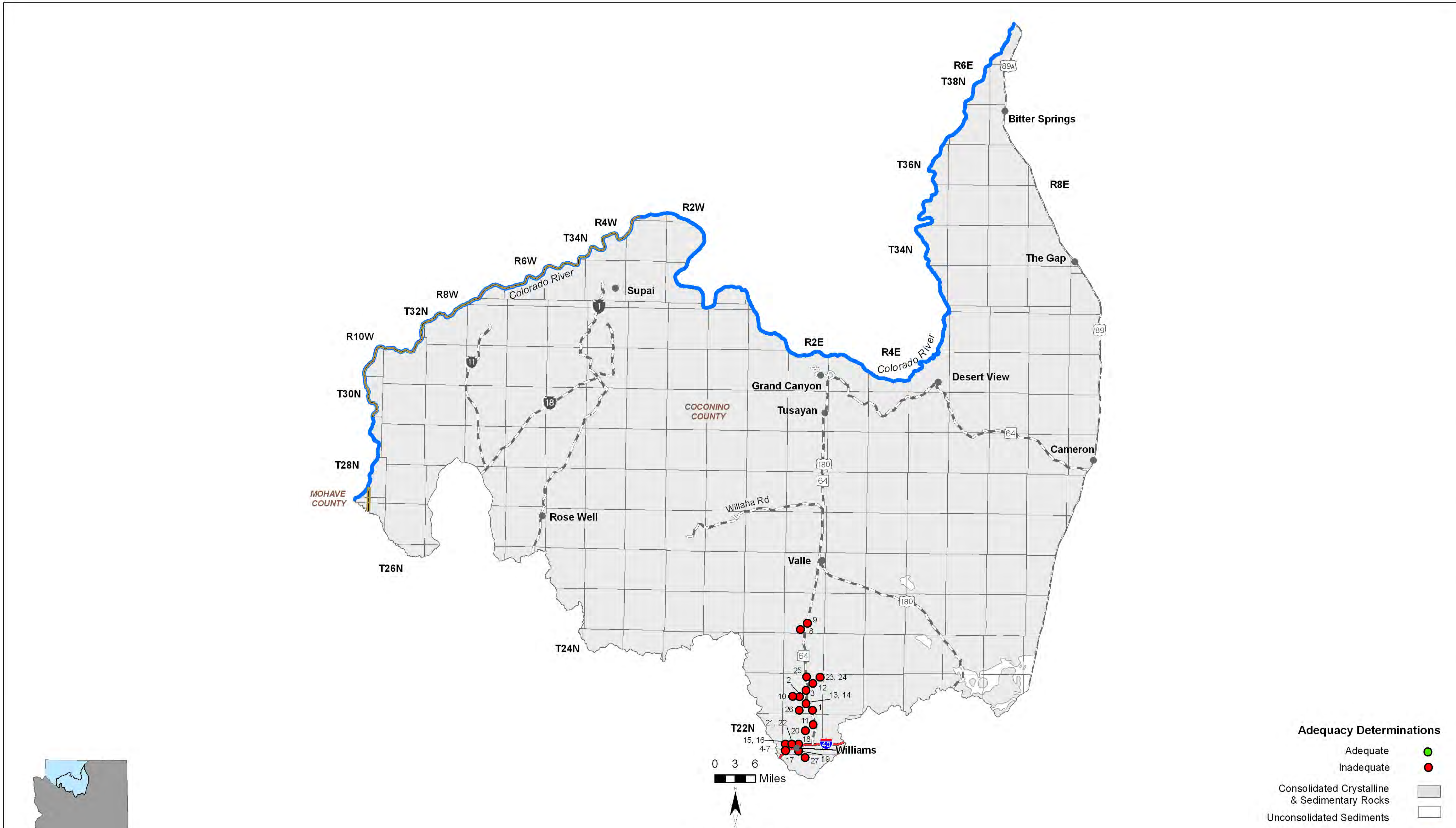


Figure 6.1-12
Coconino Plateau Basin
Adequacy Determinations

Coconino Plateau Basin

References and Supplemental Reading

References

A

Arizona Corporation Commission (ACC), 2005, Annual reports, Private Sewer companies, 1990 to 2005: ACC Utilities Division.

______, 2005, Annual reports, Small water providers, 1990 to 2005: ACC Utilities Division.

Arizona Crop and Livestock Reporting Service, 1973, 1972 Arizona Agricultural Statistics: Bulletin S-8.

Arizona Department of Economic Security (DES), 2005, Workforce Informer: Data file, accessed August 2005, http://www.workforce.az.gov.*

Arizona Department of Environmental Quality, 2005, Active dairy farms & feedlots: Data file, received October 2005.

______, 2005, ADEQSWI: Data file, received September 2005.

______, 2005, ADEQWATP: Data file, received May 2005.

______, 2005, ADEQWWTP: Data file, received August 2005.

______, 2005, Azurite: Data file, received September 2005.

______, 2005, Effluent dependent waters: GIS cover, received December 2005.*

______, 2005, Impaired lakes and reaches: GIS cover, received January 2006.

______, 2005, Surface water sources used by water providers: Data file, received June 2005.

______, 2005, WWTP and permit files: Miscellaneous working files, received July 2005.*

______, 2004, Water providers with arsenic concentrations in wells over 10ppb: Data file, received August 2004.

______, 2004, Water quality exceedences by watershed: Data file, received June 2004.*

______, 2004, Water quality exceedences for drinking water providers in Arizona: Data file, received September 2004.*

Arizona Department of Mines and Mineral Resources (ADMMR), 2005, Active mines in Arizona: Database, accessed at http:// www.admmr.state.az.us.

Arizona Department of Water Resources (ADWR), 2006, Assured and adequate water supply applications: Project files, ADWR Hydrology Division.*

______, 2005, Agricultural Surface Water Use Estimates: Unpublished analysis, ADWR Office of Resource Assessment Planning.*

______, 2005, Automated recorder sites: Data files, ADWR Basic Data Unit.*

______, 2005, 2004 rural water provider questionnaire: Data files, ADWR Office of Resource Assessment Planning.*

______, 2005, Assured and adequate water supply determinations: Database, ADWR Office of Assured and Adequate Water Supply.*

______, 2005, Flood warning gages: Database, ADWR Office of Water Engineering.*

______, 2005, Inspected dams: Database, ADWR Office of Dam Safety.*

______, 2005, Non-jurisdictional dams: Database, ADWR Office of Dam Safety.*

______, 2005, Groundwater Site Inventory (GWSI): Database, ADWR Hydrology Division.*

______, 2005, Registry of surface water rights: ADWR Office of Water Management.*

______, 2005, Water Protection Fund: Database, ADWR Office of Drought, Conservation and Riparian Planning.*
______, 2005, Water use by golf courses in rural Arizona: Unpublished analysis, ADWR Office of Regional Strategic Planning.*
______, 2005, Wells55: Database.*
______, 2002, Groundwater quality exceedences in rural Arizona from 1975 to 2001: Data file, ADWR Office of Regional Strategic Planning.*
_____, 1994, Arizona Water Resources Assessment, Vol. I, Inventory and Analysis.*
_____, 1994, Arizona Water Resources Assessment, Vol. II, Hydrologic Summary.*
_____, 1990, Draft outline of basin profiles for the state water assessment: ADWR Statewide Planning Division, Memorandum to L. Linser, D.W., January, 16, 1990.*
Arizona Game and Fish Department, 2005, Arizona Waterways: Data file, received April 2005.*
_____, 1997 & 1993, Statewide riparian inventory and mapping project: GIS cover.
_____, 1982, Arizona Lakes Classification Study.
Arizona Land Resource Information System (ALRIS), 2005, Springs: GIS cover, accessed January 2006 at http://www.land.state.az.us/alris/index.html.*
_____, 2005, Streams: GIS cover, accessed 2005 at http://www.land.state.az. us/alris/index. html.*
_____, 2005, Water features: GIS cover, accessed July 2005 at http://www.land.state.az. us /alris/ index.html.*
_____, 2004, Land ownership: GIS cover, accessed in 2004 at http://www.land.state.az. us/alris/index.html.*
Arizona Meteorological Network (AZMET), 2005, Arizona climate stations: Pan evaporation data, accessed December 2005 at http://www.ag.arizona.edu /azmet/locate.html.
Arizona Water Commission, 1975, Summary, Phase I, Arizona State Water Plan, Inventory of resource and uses.

B

Bills, D.J., and Flynn, M.E., 2002, Hydrogeologic data for the Coconino Plateau and adjacent areas, Coconino and Yavapai counties, Arizona: USGS Scientific Investigations Report 2005-5222*
_____, 2002, Hydrogeologic data for the Coconino Plateau and adjacent areas, Coconino and Yavapai counties, Arizona: USGS Open- File Report 02-265*
Bureau of Reclamation, 2002, Grand Canyon National Park water supply appraisal study, Coconino, Mohave and Yavapai Counties, Arizona: Grand Canyon National Park report.*
_____, 2006, North Central Arizona Water Supply Study: Report*

D

Diroll, M., and Marsh, D., 2006, Status of water quality in Arizona-2004 integrated 305(b) assessment and 303(d) listing report: ADEQ report.*

E

Environmental Protection Agency (EPA), 2005, Surf Your Watershed: Facility reports, accessed April 2005 at http://oaspub.epa.gov/enviro/ef_home2.water.*
_____, 2005, 2000 and 1996, Clean Watershed Needs Survey: datasets, accessed March 2005 at

http://www.epa.gov/owm/mtb/cwns/index.htm.*

F

Fisk, G.G., Duet, D.W., Evans, C.E., Angernoth, N.K., and Longsworth, S.A., 2004, Water Resources Data, Arizona Water Year 2003: USGS Water-Data Report AZ-03-1.*

G

Grand Canyon Wildlands Council, 2002, Arizona Strip Springs, Seeps and Natural Ponds: Inventory, Assessment and Development of Recovery Priorities: AZ Water Protection Fund 99-074.*

K

Kessler, J.A., 2002, Grand Canyon Springs and the Redwall-Muav aquifer: Comparison of Geologic Framework and Groundwater Flow Models: Northern Arizona University, M.S. thesis, 122 p.*

Konieczki, A.D. and Wilson, R.P., 1992, Annual summary of ground-water conditions in Arizona, spring 1986 to spring 1987: USGS Open File Report 92-54.*

M

McCormack, H.F., Fisk, G.G., Duet, N.R., Evans, D.W., Roberts, W.P., and Castillo, N.K., 2002, Water resources data Arizona, water year 2002: USGS Water Data Report AZ-02-1.*

Montgomery, E.L., 2000, Groundwater Beneath Coconino and Sand Francisco Plateaus: Presented at the First Coconino Plateau Hydrology Workshop, October 2000, Flagstaff, Arizona.*

N

National Park Service, 2004, Grand Canyon springs: Electronic data file, sent November 2004*

______, 1999, Protection of spring and seep resources of the South Rim, Grand Canyon National Park by measuring water quality, flow and associated biota: Arizona Water Protection Fund Project 99-071.*

Natural Resources Conservation Service (NRCS), 2005, SNOTEL (Snowpack Telemetry) stations: Data file, accessed December 2005 at http://www3.wcc.nrcs.usda.gov /nwcc/sntlsites.jsp?state=AZ.*

______, 2005, Snow Course stations: Data file, accessed December 2005 at http://www.wcc.nrcs.usda.gov/nwcc/snow-course-sites.jsp?state=AZ.*

O

Oregon State University, Spatial Climate Analysis Service (SCAS), 2006, Average annual precipitation in Arizona for 1961-1990: PRISM GIS cover, accessed in 2006 at www.ocs.orst.edu/prism.*

P

Pope, G.L., Rigas, P.D., and Smith, C.F., 1998, Statistical summaries of streamflow data and characteristics of drainage basins for selected streamflow-gaging stations in Arizona through water year 1996: USGS Water Resources Investigations Report 98-4225.*

Price, D., and Arnow, T., 1974, Summary appraisals of the nation's groundwater resources, Upper Colorado region: USGS Professional Paper 813-C.*

T

Tadayon, S., 2004, Water withdrawals for irrigation, municipal, mining, thermoelectric-power, and drainage uses in Arizona outside of the active management areas, 1991-2000: USGS Scientific Investigations Report 2004-5293, 27 pp.*

Taylor, H.E., Peart, D.B., Antweiler, R.C., and others, 1996, Data from synoptic water quality studies on the Colorado River in the Grand Canyon, Arizona, November 1990 to June 1991: USGS Open File Report 96-614.*

U

US Army Corps of Engineers, 2004 and 2005, National Inventory of Dams: Arizona Dataset, accessed November 2004 to April 2005 at http://crunch.tec.army.mil /nid/webpages/nid.cfm*

US Geological Survey (USGS), 2006, Average annual runoff in the United States, 1951-1980: Data file, accessed March 2006 at http://aa179.cr.usgs.gov/metadata /wrdmeta/runoff.htm.*

_____, 2006, Springs and spring discharges: Dataset, received November 2004 and January 2006 from USGS office in Tucson, AZ.*

_____, 2006, National Hydrography Dataset: Arizona dataset, accessed at http://nhd.usgs.gov/.*

_____, 2005, National Water Information System (NWIS): Arizona dataset, accessed December 2005 at http://waterdata.usgs.gov/nwis.*

_____, 2004, Southwest Regional Gap analysis study- land cover descriptions: Electronic file, accessed January 2005 at http://earth.gis.usu.edu/swgap.*

_____, 2004, Assessment of spring chemistry on the South Rim of the Grand Canyon National Park, Arizona: USGS Fact sheet 096-02.*

_____, 1981, Geographic digital data for 1:500,000 scale maps: USGS National Mapping Program Data Users Guide.*

V

Valencia, R.A., Wennerlund, J.A., Winstead, R.A., Woods, S., Riley, L., Swanson, E., and Olson, S., 1993, Arizona riparian inventory and mapping project: Arizona Game and Fish Department.*

W

Wahl, C.R., Boe, S.R., Wennerlund, R.A., Winstead, R.A., Allison, L.J., Kubly, D.M., 1997, Remote sensing mapping of Arizona intermittent stream riparian areas: Arizona Game and Fish Technical Report 112.*

Water Infrastructure Finance Authority of Arizona (WIFA), 2005, Clean Watershed Needs Survey-2004: Unpublished data sheets, received July 2005.*

_____, 2004, Priority funding list applications.

Wenrich, K.J., Boundt, S.Q., and others, 1993, Hydrochemical survey for mineralized breccia pipes- data from springs, wells and streams on the Hualapai Indian Reservation,

northwestern Arizona: USGS Open File Report 93-619.
Western Regional Climate Center (WRCC), 2005, Pan evaporation stations: Data file accessed December 2005 at http://www4.ncdc.noaa.gov/cgi-win/wwcgi.dll?wwDI~GetCity~USA.*
_____, 2005, Precipitation and temperature stations: Data file, accessed December 2005 at http://www4.ncdc.noaa.gov/cgi-win/wwcgi.dll?wwDI~GetCity~USA.*
Wilson, E., 2000, Geologic framework and numerical groundwater models of the south rim of the Grand Canyon, Arizona: Northern Arizona University, M.S. thesis, 72 p.*
Wilson, R.P., 1992, Summary of groundwater conditions in Arizona 1985 to 1986: USGS Water Resources Investigation Report, 90-4179.*

*All references marked with an asterisk contain information that was directly used in the basin summaries, tables or maps.

Supplemental Reading

Adams, E., 2004, Spring flow and timing of the south rim springs of the Grand Canyon, Arizona using modified electrical resistance sensors: in The Value of Water; Proceedings from the 17th annual Arizona Hydrological Society symposium, September 2004, Tucson Arizona.

Amentt, M., Springer, A.E., and DeWald, L., 2000, Restoration of perched aquifer system through manipulation of transpiration at the watershed scale: Geology Society of America: Abstracts with Programs, vol. 32, p. A-141.

Andersen, Mark, 2005, Assessment of water availability in the Lower Colorado River basin: in Conservation and Innovation in Water Management: Proceedings of the 18th annual Arizona Hydrological Society Symposium, Flagstaff, Arizona, September, 2005.

Appel, C.L., Bills, D.L., 1981, Maps showing ground-water conditions in the San Francisco Peaks Area, Coconino County, Arizona: USGS Open-File Report 81-914.

Bennett, J.B., Parnell, R.A., Meyer, W.A., Black, C.R., Petrouson, C.R., William. K.T., and Webb K.T., 1994, Impacts of flow regulation of the Colorado River on biogeochemical cycling in riparian environments, Grand Canyon National Park, Arizona: in Abstracts with Programs: Geological Society of America, vol. 26, no. 7, p A. 99.

Bennett, J. B. and Parnell, R. A., Jr., 1995, Nutrient Cycling in the Colorado, Grand Canyon National Park, AZ, USA: 3rd Biennial Conference on the Colorado Plateau, Flagstaff, AZ.

Bennett, J.B., 1997, A Biogeochemical Characterization of Reattachment Bars of the Colorado River, Grand Canyon National Park, Arizona: Northern Arizona University, M.S. thesis, 148 p.

Black, K., Prudhom, B., and Miller, M., 2006, C aquifer water supply study: Bureau of Reclamation, Report of Findings.

Carpenter, M.C., Carruth, R.L., Fink, J.B., Boling, J.K., and Cluer, B.L., 1995, Hydrology and deformation of sand bars in response to fluctuations of the Colorado River in the Grand Canyon, Arizona: USGS Water Resources Investigations Report 95-4010, 16 p.

City of Williams, 2006, Water System Plan: Submitted to the Arizona Department of Water Resources.

City of Williams, 2002, Coconino plateau regional water study: Arizona Water Protection Fund Project 99-093

Coconino County, 1997, Tusayan Area Plan and Design Review Overlay, Area Plan Approved by the Coconino County Board of Supervisors April 7, 1995 & Amended May 5, 1997.

Enzel, Y., Ely, L.L., House, P.K., Baker, V.R., and Webb, R.H., 1993, Paleoflood evidence for a natural upper bound to flood magnitudes in the Colorado River Basin: Water Resources Research, vol. 29, no. 7, p. 2287-2297.

Farrar, C.D., 1979, Map showing ground-water conditions in the Bodaway Mesa area, Coconino County, Arizona: USGS Open-File Report 79-1488.

Flynn, M.E., and Bills, D.J., 2002, Investigation of the geology and hydrology of the Coconino Plateau of Northern Arizona: A project of the Arizona Rural Watershed Initiative: USGS Fact Sheet 113-02, 4 p.

Flynn, M., Hornewer, N., 2003, Variations in sand storage measured at monumented cross sections in the Colorado River between Glen Canyon and Lava Falls Rapid, Northern Arizona, 1992-1999:USGS Water Resources Investigations Report 03-4104, 39 p.

Freilich, Leitner & Carlisle, 2005, Mohave County General Plan: Water Resources Element.

Garrett, W.B., Van De Vanter, E.K., and Graf, J.B., 1993, Stream flow and sediment-transport data, Colorado River and three tributaries in the Grand Canyon, Arizona, 1983 and 1985-1986: USGS Open–File Report 93-174, 624 p.

Gauger, R.W., 1997, River-stage data Colorado River, Glen Canyon Dam to upper Lake Mead, Arizona, 1990-1994: USGS Open–File Report 96-626, 20 p.

Gavin, A.J., 1998, Hydrogeology and Numerical Simulation of a Spring-Dominated High-Elevation Riparian Community, Hart Prairie, Arizona: Northern Arizona University, M.S. thesis, 177 p.

Gavin, A.J., and Springer, A.E., 1997, Conservation of a rare riparian community through hydrological restoration: Geological Society of America, Abstracts with Programs, v. 29, p. 178.

Gilbert, B.A., 1997, Hydrogeologic parameters necessary to conserve backwater habitats of the Colorado River, Grand Canyon, Arizona: Geological Society of America, Abstracts with Programs, vol. 29, p. 177.

Harms, R. 2005, Grand Canyon National Park springs, seeps, hanging gardens and tinajas summary: NPS, Southern Colorado Network.

Hart, R.J., 1999, Water Quality of the Colorado River monitored by the USGS National Stream Quality Accounting Network: in Water Issues and Partnerships for Rural Arizona: Proceedings of the 12 annual symposium of the Arizona Hydrological Society, September 1999, Hon Dah, Arizona.

Hart, R.J., Rihs, J., Taylor, H.E., and Monroe, S.A., 2002, Assessment of spring chemistry along the south rim of the Grand Canyon National Park, Arizona: USGS Fact Sheet FS 096-02, 4 p.

Hazel, J. Jr., Kaplinski, M.A., Parnell, R.A. Jr., Manone, M., and Dale, A., 1999, Effects of the 1996 beach/habitat-building flow on Colorado River sand bars and sediment storage along the Colorado River Corridor; in The Controlled Flood in Grand Canyon, Webb, R.H., Schmidt, J. S., Marzolf, G. R., and Valdez, R. A. (eds): AGU Geophysical Monograph 110, American Geophysical Union, Washington, DC.

Heffernon, R., Muro, M., 2001, Growth on the Coconino Plateau-potential impacts of a water pipeline for the region: Morrison Institute for Public Policy report.

Hereford, R., Webb, G., and Graham, S., 2002, Precipitation history of the Colorado Plateau region, 1990 – 2000: USGS Fact sheet 119-02.

Huntoon, P.W., 1996, Large basin groundwater circulation in paleo-reconstruction of circulation leading to uranium mineralization in Grand Canyon breccia pipes, Arizona: The Mountain Geologist, vol.33, no. 3, 71-84 p.

HydroResources (Town of Tusayan), 2007, Water System Plan, Submitted to the Arizona Department of Water Resources.

Kaplinski, M.A., Bennett, J. Hazel, J. Jr., Manone, M., Parnell, R.A. Jr., and Cain, J., 1998, Fluvial habitats developed on sand bars, Colorado River, Grand Canyon: EOS, Transactions of the American Geophysical Union, v. 49.

Kaplinski, M.A., Hazel, J. Jr., Parnell, R.A. Jr., Manone, M., Dale, A. and Topping, D., 1998, Sediment storage changes following short-duration high magnitude flow releases from Glen Canyon Dam, Grand Canyon National Park: Geological Society of America, Abstracts with Programs, v. 30, p 12.

Kessler, J.A., 2002, Grand Canyon Springs and the Redwall - Muav Aquifer: Comparison of geologic framework and groundwater flow models: Northern Arizona University, M.S. thesis, 122 p.

Kessler, J.A., Springer, A.E., 2000, Comparison of digital geologic framework models of the Redwall - Muav Aquifer, Grand Canyon, Arizona: Geological Society of America, Abstracts with Programs, 32; 7, p. 141.

Kobor, J.S., 2004, Simulating water availability in a spring fed aquifer with surface/groundwater flow models, Grand Canyon Arizona: Northern Arizona University M.S. thesis.

Kobor, J.S., Springer, A.E., 2003, Predicting riparian vegetation response to groundwater withdrawals; an interdisciplinary modeling approach to a regional spring system, Grand Canyon, AZ: Geological Society of America, Abstracts with Programs, vol. 35, 6, p. 374 .

Melis, T.S., Phillips, W.M., Webb, R.H., and Bills, D.J., 1996, When blue-green waters turn red, historical flooding in Havasu Creek, Arizona: USGS Water Resource Investigations 96-4059.

Mondry, Z., 2002, Drought, storms, and stream flow and temperature observations from the Coconino and Prescott National Forests: on Sustainability Issues of Arizona's Regional Watersheds: Proceedings from the 16th annual Arizona Hydrological Society Symposium, September 2003, Mesa, Arizona

Manone, M., Hazel, J. Jr., Kaplinski, M.A., Parnell, R.A. Jr., and Dexter, L., 1996, Monitoring the effects of flow regulation from Glen Canyon Dam on Colorado River sand bars: EOS, Transactions of the American Geophysical Union, v. 47, p. 273.

Monroe, S.A., Antweiler, R.C., Hart, R.J, Taylor, H.E., Truini, M., Ruhs, J.R. and Felger, T.J., 2005, Chemical characteristics of groundwater discharge along the south rim of the Grand Canyon, in Grand Canyon National Park, Arizona, 2000-2001: USGS Scientific Investigations Report 2004-5146, 71 pp.

Montgomery, E.L., 2003, R-Aquifer in northern Arizona: in Sustainability Issues of Arizona's Regional Watersheds: Proceedings from the 16th annual Arizona Hydrological Society Symposium, September 2003, Mesa, Arizona.

Montgomery, E.L., 1997, Hydrology of the Missippian-Cambrian Redwall - Muav Carbonate Aquifer (R Aquifer system) and the potential impact of development along the Grand Canyon south rim: in Arizona's Water: Looking for the Next Waterhole: Proceedings from the 10th annual Arizona Hydrological Society Symposium, September 1997, Carefree, Arizona, p. 24.

Montgomery, E.L, 1993, Projections for decrease in spring flow resulting from proposed groundwater withdrawal near Tusayan, Arizona: Canyon Forest Village Report.

National Park Service, Grand Canyon National Park, 2006, Water System Plan: Submitted to the Arizona Department of Water Resources.

O'Day, C. M., and Leake, S. A., 1995, Ground water availability in the Flagstaff area of the Colorado Plateau, Arizona: in Water Use in Arizona: Cooperation or Conflict?: Proceedings from the 8th annual Arizona Hydrological Society Symposium, September 1995, Tucson, Arizona, p. 2-3.

Parnell, R.A. Jr., Springer, A., Stevens, L., Bennett, J., Hoffnagle, T., Melis, T., and Staniski-Martin, D., 1997, Flood-induced backwater rejuvenation along the Colorado River Corridor in Grand Canyon, AZ.: in Symposium on the Glen Canyon Dam Beach/Habitat-Building Flow, Patten, D. and Garrett, L. (eds.): U.S. Bureau of Reclamation/GCMRC, Flagstaff, AZ, p. 41-51.

Parnell, R.A. Jr., Bennett, J., and Stevens, L., 1999, Floods bury riparian vegetation: Impacts of the 1996 controlled flood of the Colorado River in Grand Canyon on nutrient concentrations in bar/eddy complexes; in The Controlled Flood in Grand Canyon, Webb, R.H., Schmidt, J. S., Marzolf, G. R., and Valdez, R. A. (eds): AGU Geophysical Monograph 110, American Geophysical Union, Washington, DC.

Petroutson, W.D., 1997, Interpretive simulations of advective flowpaths across a reattachment bar during different Colorado River flow alternatives: Northern Arizona University, M.S. thesis, 159 p.

Petroutson, W. D., Springer, A.E., 1995, Characterizing stage-dependent measurements of hydraulic conductivity of reattachment bars in the Colorado River: Geological Society of America, Abstracts with Programs, v. 27; p. 34.

Petroutson, W. D., Springer, A.E., Parnell, R.A., Jr., and Bennett, J.B., 1995, Hydrogeology of reattachment bars on the Colorado River: 3rd Biennial Conf. on the Colorado Plateau, Flagstaff, AZ.

Petroutson, W. D., Bennett, J.B., Parnell, R.A., Jr., and Springer, A.E., 1995, Hydraulic-conductivity measurements of reattachment bars on the Colorado River: Proceedings of the 1995 meeting of the Arizona Section, American Water Resource Association and the Hydrology Section, Arizona-Nevada Academy of Science, vol. 22-25, p.7-10.

Pierce, H.A., 2001, Structural controls on groundwater conditions and estimated aquifer properties near Bill Williams Mountain, Williams Arizona: USGS Water Resources Investigation Report 01- 4058.

Rocky Mountain Institute, 2002, North central Arizona water demand study: Phase 1, draft report.

Rote, J.J., Flynn, M.E., and Bills, D.J., 1997, Hydrologic data, Colorado River and major tributaries, Glen Canyon Dam to Diamond Creek, Arizona, water years 1990 -1995: USGS Open – File Report 97-250, 474 p.

Ross, L.E., 2003, Roaring Springs, Grand Canyon, Arizona: New data sets provide tools for improved recharge area delineation: in Sustainability Issues of Arizona's Regional Watersheds: Proceedings from the 16th annual Arizona Hydrological Society Symposium, September 2003, Mesa, Arizona.

Ross, L.E. and Springer, A.E., 2002, Interactive three-dimensional visualization for digital hydrogeologic framework models: GeoWall presentation of the Grand Canyon, 2002 Fall meeting of the American Geophysical Union.

S. S. Papadopulas & Associates, 2005, Groundwater flow model for the C-aquifer in Arizona and New Mexico: Report for Southern CA Edison, SRP, and Nevada Power Co.

Semmens, B.A., 1999, Hydrogeologic characterization and numerical transport simulations of a reattachment-bar aquifer in the Colorado River: Northern Arizona University, M.S. thesis, 188 p.

Stevens, L.E., Shannon, J.P., and Blinn, D.W.,, 1997, Colorado River benthic ecology in Grand Canyon Arizona, USA: dam, tributary and geomorphological influences: Regulated Rivers: Research and Management 13:129-149.

Stevens, L.E., Schmidt, J.C., Ayers, T.J., Brown, B.T., 1995, Flow regulation, geomorphology and Colorado River marsh development in the Grand Canyon, Arizona: Ecological Applications 5:1025-1039.

Smith J.D., and Wiele, S., 1991, Flow and sediment transport in the Colorado River between Lake Powell and Lake Mead: USGS report 38 p.

Springer, A.E., 1999, Threats to the values of springs and riparian ecosystems of the Grand Canyon by ground-water mining: Geological Society of America, 1999 annual meeting, Denver, CO, United States, Oct. 25-28, 1999: Abstracts with Programs 31; 7, p.23

Springer, A.E., and Kessler, J. A., 2003, Groundwater model of the Redwall-Muav aquifer of the Coconino Plateau incorporating impacts of pumping and water conservation on small springs of the Grand Canyon: Geological Society of America, Abstracts with Programs, vol. 35.

Springer, A.E. and Bills, D., 1998, Exploration for and ecological importance of shallow and deep ground-water around San Francisco Mountain: in Geologic Excursions in Northern and Central Arizona, Duebendorfer, E.M., (ed.), p. 27-33.

Topping, D.J., Schmidt, J.C., and Vierra, L.E., Jr., 2003, Computation and analysis of the instantaneous-discharge record for the Colorado River at Lees Ferry, Arizona, May 8, 1921, through September 30, 2000: USGS Professional Paper 1677.

United States Forest Service, 1999, Final environmental impact statement for Tusayan growth, Coconino County, Arizona: USDA report.

United States Geologic Survey, Calculated hydrographs for the Colorado River downstream from Glen Canyon Dam during the experimental release, March 22-April 8, 1996: USGS Fact Sheet 083-96.

Victor, W.R., Lindquist, J.C., and Montgomery, E.L., 1999, Groundwater resources and potential impacts from the development, Tusayan Growth EIS: in Water Issues and Partnerships for Rural Arizona: Proceedings from the 12th annual Arizona Hydrological Society Symposium, September 1999, Pinetop, Arizona.

Ward, J., 2002, Groundwater on the Plateau: Southwest Hydrology, Vol.1, No. 4.

Wilson, E., 2000, Geologic framework and numerical groundwater models of the south rim of the Grand Canyon, Arizona: Northern Arizona University, M.S. thesis, 72 p.

Wilson, E.S., Springer, A.E., Winter, C.L., 1999, Delineating spring capture zones for the south rim of the Grand Canyon, Arizona, using framework and numerical models: Geological Society of America, Abstracts with Programs, vol. 31, 7, p. 347.

Woodhouse, B.G., Parker, J.T.C., Bills, D.J., and Flynn, M.E., 2000, USGS investigation of rural Arizona watersheds: Coconino Plateau, Upper and Middle Verde River, and Fossil Creek-East Verde River -Tonto Creek: on Environmental Technologies for the 21st Century: Proceedings from the 13th annual Arizona Hydrological Society Symposium, September 2000, Phoenix, Arizona, p. 97.

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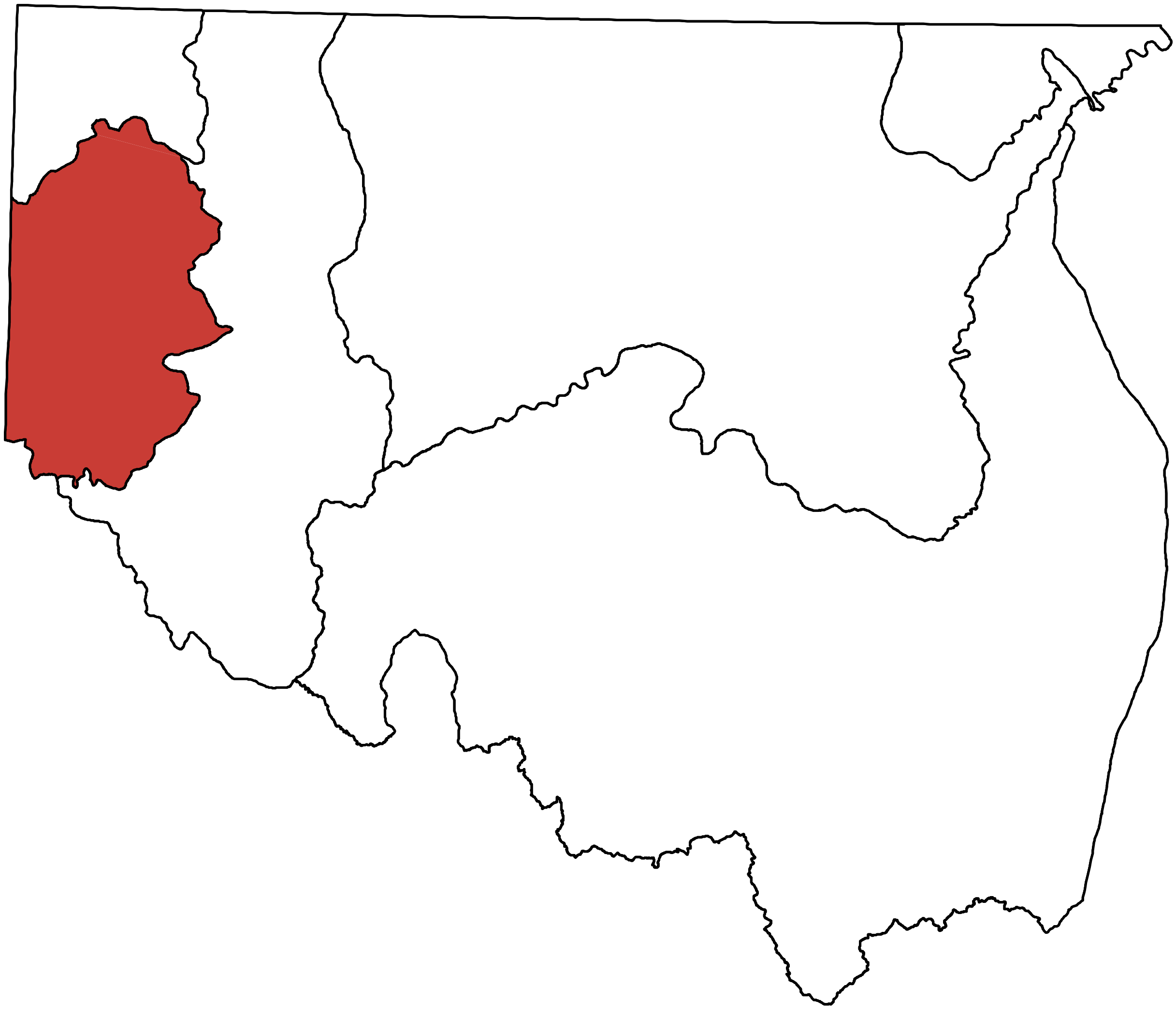
Section 6.2
Grand Wash Basin



6.2.1 Geography of the Grand Wash Basin

The Grand Wash Basin, located in the western part of the planning area is 959 square miles in area. Geographic features and principal communities are shown on Figure 6.2-1. The basin is characterized by cliffs and washes. Vegetation is primarily Mohave desertscrub and Great Basin conifer woodland with small areas of Great Basin desertscrub, interior chaparral and plains grassland. (See Figure 6.0-9)

- Principal geographic features shown on Figure 6.2-1 are:
    - Basin places of Pakoon Spring and Tassi Spring
    - Lake Mead forming the southwestern basin boundary
    - Grand Wash in the western portion of the basin
    - Grand Wash and Upper Grand Wash Cliffs running north-south through the basin
    - Mud Mountain in the northern portion of the basin
    - The highest point in the basin, Last Chance Knoll, at 6,758 feet

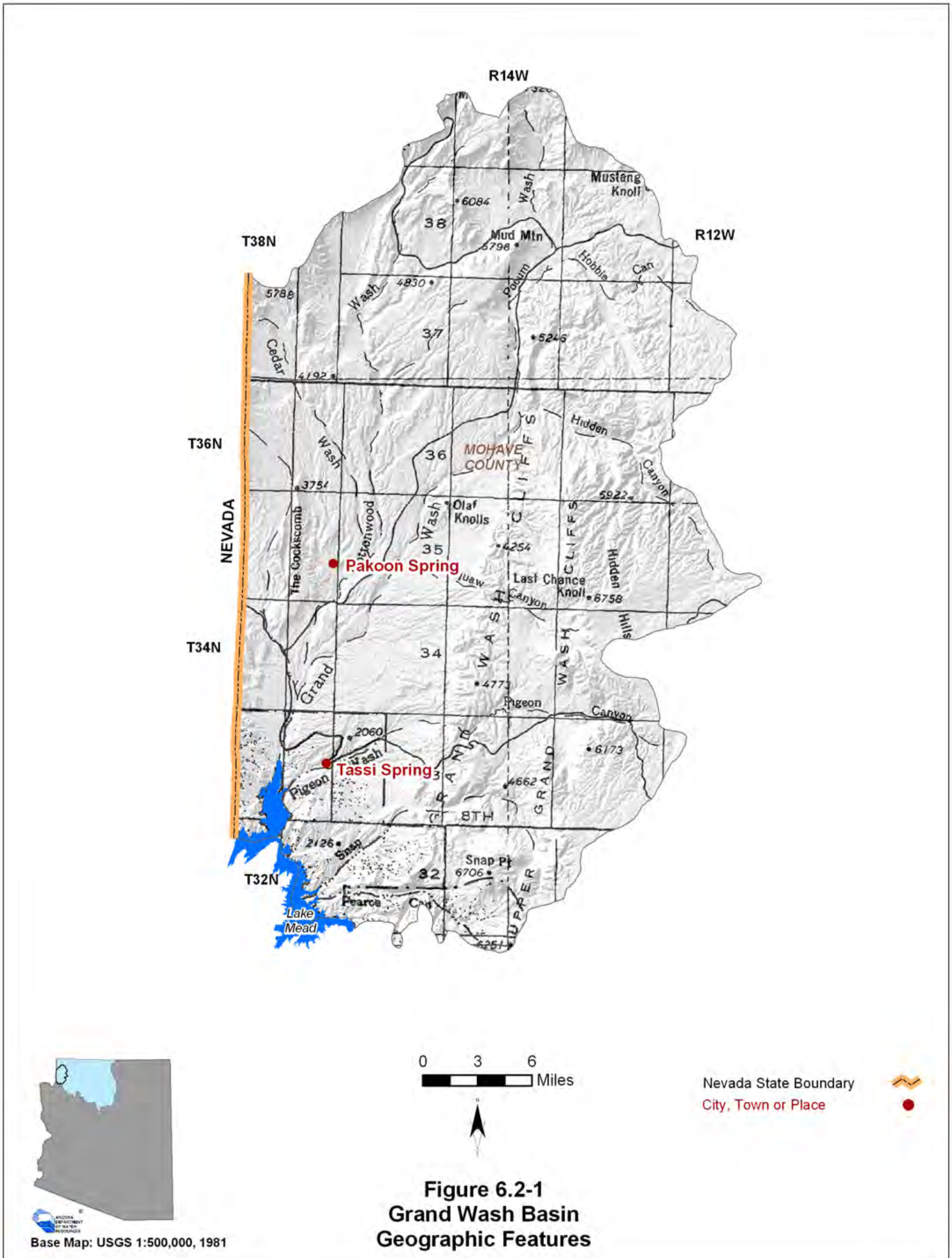


Figure 6.2-1
Grand Wash Basin
Geographic Features

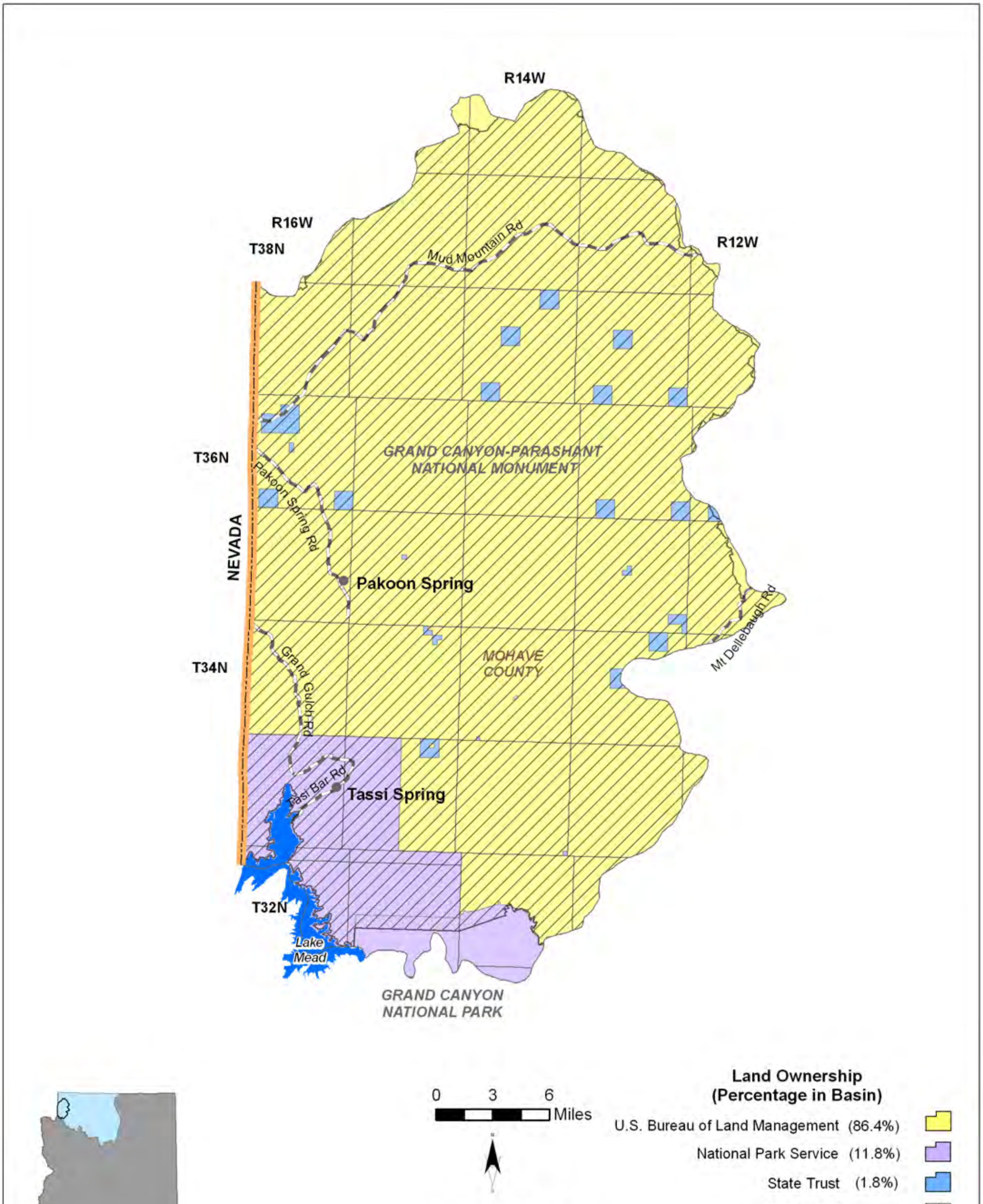
6.2.2 Land Ownership in the Grand Wash Basin

Land ownership, including the percentage of ownership by category, for the Grand Wash Basin is shown in Figure 6.2-2. The principal feature of land ownership in this basin is the large portion of land, 96% of the total basin area, within the Grand Canyon-Parashant National Monument managed by the U.S. Bureau of Land Management and the National Park Service. A description of land ownership data sources and methods is found in Volume 1, Section 1.3.8. Land ownership categories are discussed below in the order of percentage from largest to smallest in the basin.

U.S. Bureau of Land Management (BLM)
- 86.4% of the land is federally owned and managed by the Arizona Strip Field Office of the Bureau of Land Management.
- Most of the BLM lands in this basin are part of the Grand Canyon-Parashant National Monument, which also includes two wilderness areas, Grand Wash Cliffs (37,030 acres, entire) and Paiute (87,900 acres, portion).
- Land uses include resource conservation, recreation and grazing.

National Park Service (NPS)
- 11.8% of the land is federally owned and managed by the National Park Service as the Grand Canyon-Parashant National Monument and Grand Canyon National Park.
- Land uses include resource conservation and recreation.

State Trust Land
- 1.8% of the land is held in trust for the public schools under the State Trust Land system.
- All state land is interspersed with BLM land and is included within the boundaries of the Grand Canyon-Parashant National Monument.
- Primary land use is grazing.



Source: ALRIS, 2004
Bureau of Land management, 1999 & 2000

Figure 6.2-2
Grand Wash Basin
Land Ownership

6.2.3 Climate of the Grand Wash Basin

The Grand Wash Basin does not contain NOAA/NWS, Evaporation Pan, AZMET or SNOTEL/Snowcourse stations. Figure 6.2-3 shows precipitation contour data from the Spatial Climate Analysis Service (SCAS) at Oregon State University. A description of the climate data sources and methods is found in Volume 1, Section 1.3.3.

SCAS Precipitation Data

- See Figure 6.2-3
- Average annual rainfall is as high as 16 inches in the northern portion of the basin and four inches or less near Lake Mead.

Table 6.2-1 Climate Data for the Grand Wash Basin

A. NOAA/NWS Co-op Network:

Station Name	Elevation (in feet)	Period of Record Used for Averages	Average Temperature Range (in F)		Average Precipitation (in inches)				
			Max/Month	Min/Month	Winter	Spring	Summer	Fall	Annual
None									

Source: WRCC, 2003

B. Evaporation Pan:

Station Name	Elevation (in feet)	Period of Record Used for Averages	Avg. Annual Evap (in inches)
None			

Source: WRCC, 2003.

C. AZMET:

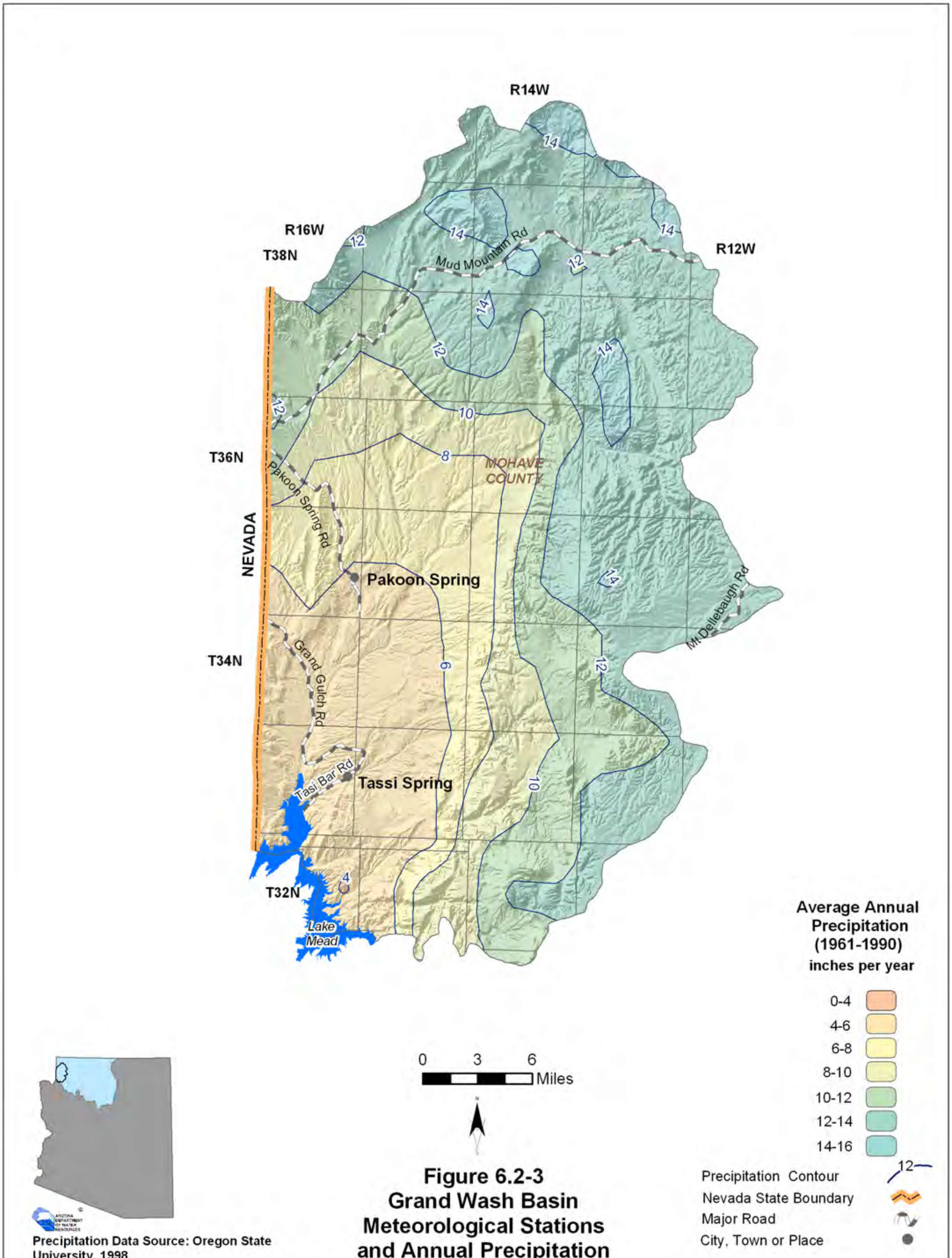
Station Name	Elevation (in feet)	Period of Record Used for Averages	Average Annual Reference Evaportranspiration, in inches (*Number of years to calculate averages*)
None			

Source: Arizona Meteorological Network, 2005

D. SNOTEL/Snowcourse:

Station Name	Elevation (in feet)	Period of Record Used for Averages	Average Snowpack, at Beginning of the Month, as Inches Snow Water Content *(Number of measurements to calculate average)*					
			Jan.	Feb.	March	April	May	June
None								

Source: NRCS, 2005



Precipitation Data Source: Oregon State University, 1998

Figure 6.2-3
Grand Wash Basin
Meteorological Stations and Annual Precipitation

6.2.4 Surface Water Conditions in the Grand Wash Basin

There are no streamflow data, flood ALERT equipment or large reservoirs in this basin. Total number of stockponds in the basin is shown on Table 6.2-4. USGS runoff contours are shown on Figure 6.2-4. A description of stream data sources and methods is found in Volume 1, Section 1.3.16. A description of reservoir data sources and methods is found in Volume 1, Section 1.3.11. A description of stockpond data sources and methods is found in Volume 1, Section 1.3.15.

Reservoirs and Stockponds

- Refer to Table 6.2-4
- There are no large or small reservoirs.
- There are 109 registered stockponds in the basin.

Runoff Contour

- Refer to Figure 6.2-4.
- Average annual runoff is highest, one inch per year or 53 acre-feet per square mile, in the northern portion of the basin near Mud Mountain Road and decreases to 0.1 inches, or five acre-feet per square mile, in most of the southern portion of the basin.

Table 6.2-2 Streamflow Data for the Grand Wash Basin

Station Number	USGS Station Name	Drainage Area (in mi^2)	Mean Basin Elevation (in feet)	Period of Record	Average Seasonal Flow (% of annual flow)				Annual Flow/Year (in acre-feet)				Years of Record
					Winter	Spring	Summer	Fall	Minimum	Median	Mean	Maximum	
None													

Sources: USGS NWIS, USGS 1998 and USGS 2003.

Table 6.2-3 Flood ALERT Equipment in the Grand Wash Basin

Station ID	Station Name	Station Type	Install Date	Responsibility
None				

Table 6.2-4 Reservoirs and Stockponds in the Grand Wash Basin

A. Large Reservoirs (500 acre-feet capacity and greater)

MAP KEY	RESERVOIR/LAKE NAME *(Name of dam, if different)*	OWNER/OPERATOR	MAXIMUM STORAGE (AF)	USE	JURISDICTION
None identified by ADWR at this time					

B. Other Large Reservoirs (50 acre surface area or greater)

MAP KEY	RESERVOIR/LAKE NAME *(Name of dam, if different)*	OWNER/OPERATOR	MAXIMUM SURFACE AREA (acres)	USE	JURISDICTION
None identified by ADWR at this time					

C. Small Reservoirs (greater than 15 acre-feet and less than 500 acre-feet capacity)

Total number: 0
Total maximum storage: 0 acre-feet

D. Other Small Reservoirs (between 5 and 50 acres surface area)

Total number: 0
Total surface area: 0 acres

E. Stockponds (up to 15 acre-feet capacity)

Total number: 109

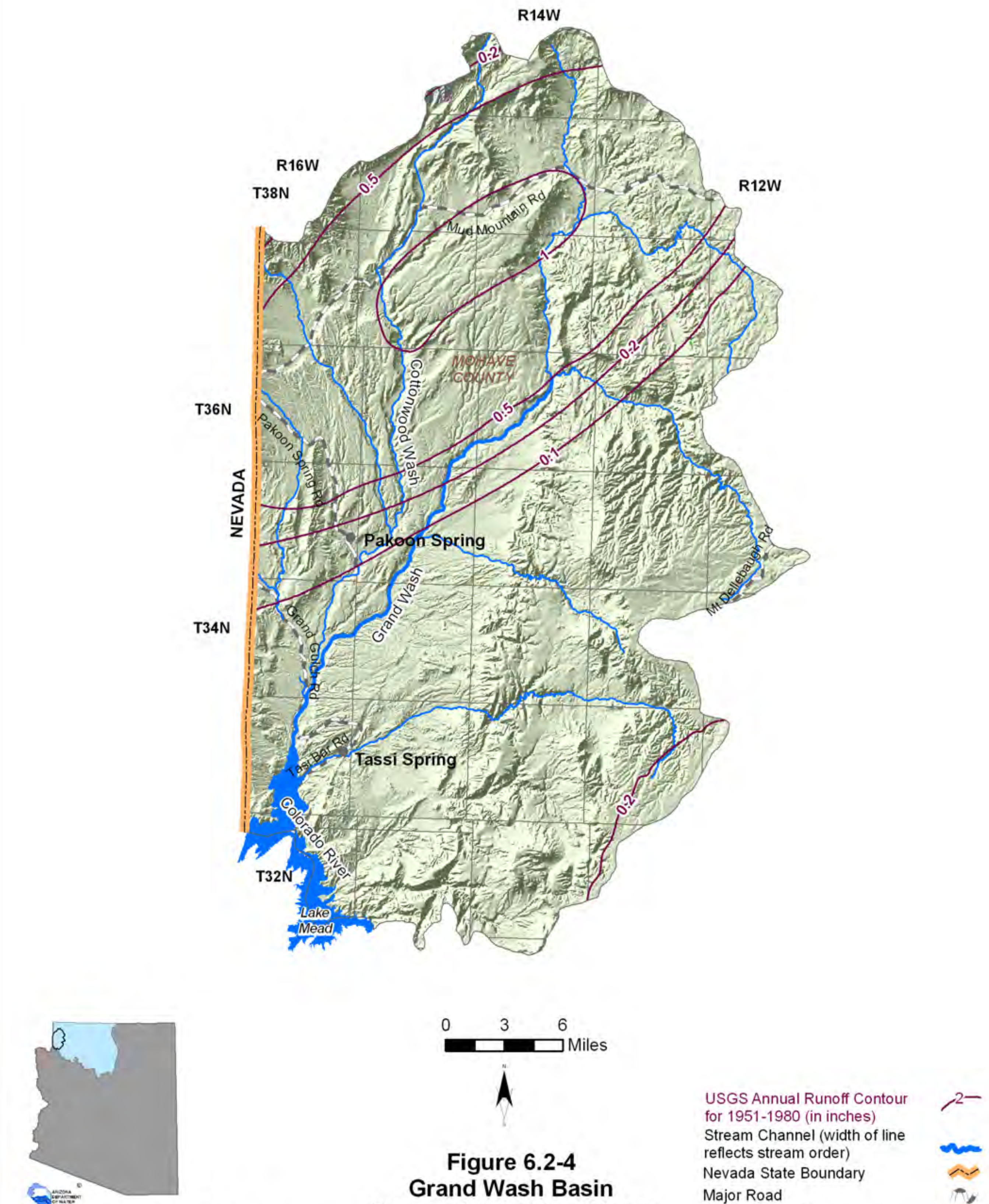


Figure 6.2-4
Grand Wash Basin
Surface Water Conditions

6.2.5 Perennial/Intermittent Streams and Major Springs in the Grand Wash Basin

Major and minor springs with discharge rates and date of measurement, and the total number of springs in the basin are shown in Table 6.2-5. The locations of major springs and one perennial stream are shown on Figure 6.2-5. A description of data sources and methods for intermittent and perennial reaches is found in Volume 1, Section 1.3.16. A description of spring data sources and methods is found in Volume 1, Section 1.3.14.

- There are no intermittent streams and the only perennial stream is the Colorado River, which is impounded at Hoover Dam, and forms Lake Mead in this basin.
- There are six major springs with a measured discharge of 10 gallons per minute (gpm) or greater at any time.
- Listed discharge rates may not be indicative of current conditions.
- All springs are located in the western portion of the basin. The greatest discharge rate was measured at Tassi Spring, 75 gpm.
- Springs with measured discharge of 1 to 10 gpm are not mapped but coordinates are given in Table 6.2-5B. There are nine minor springs in this basin.
- The total number of springs, regardless of discharge, identified by the USGS varies from 47 to 52, depending on the database reference.

Table 6.2-5 Springs in the Grand Wash Basin

A. Major Springs (10 gpm or greater):

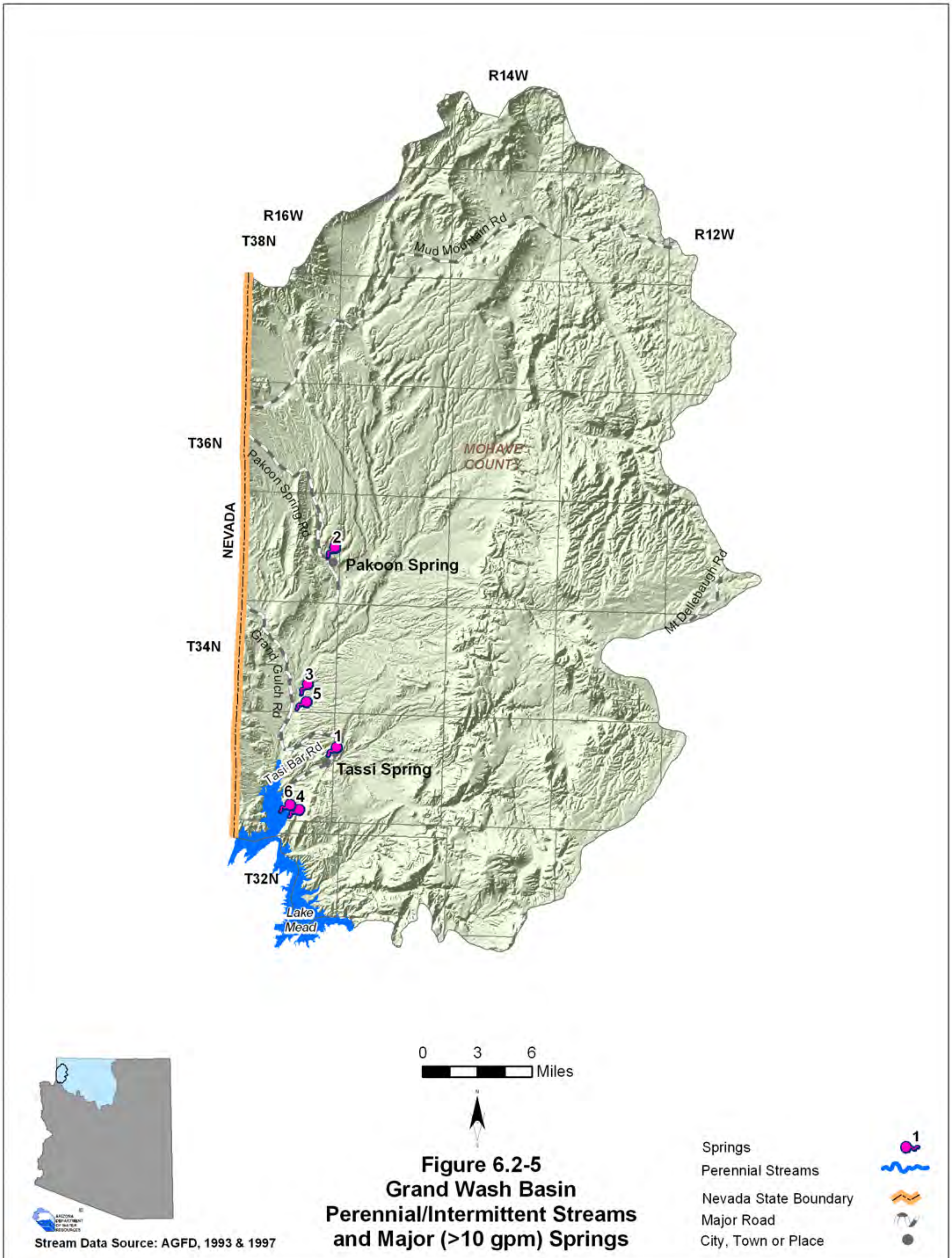
Map Key	Name	Location		Discharge (in gpm)[1]	Date Discharge Measured
		Latitude	Longitude		
1	Tassi	361523	1135728	75	5/9/2000
2	Pakoon	362457	1135726	58	5/11/2000
3	Whiskey	361848	1135851	40	2/6/1980
4	Chill Heal	361301	1135917	25	3/12/1980
5	Unnamed	361817	1135855	20	2/6/1980
6	Unnamed	361314	1135944	13	3/12/1980

B. Minor Springs (1 to 10 gpm):

Name	Location		Discharge (in gpm)[1]	Date Discharge Measured
	Latitude	Longitude		
Middle	363205	1140230	9	5/11/2000
Burro	361700	1140013	3	5/9/2000
Unnamed	361752	1135906	4	9/22/1976
Cane -south	363916	1134705	2	5/14/2000
Hidden	362812	1133741	2	5/15/2000
Mud	364145	1134644	2	5/13/2000
Unnamed	361544	1135614	2	3/12/1980
Red Rock	363303	1140124	2	5/12/2000
#106	364100	1134526	2	5/13/2000

C. Total number of springs, regardless of discharge, identified by USGS (see ALRIS, 2005 and NHD, 2006): 47 to 52

Notes:
[1] Most recent measurement identified by ADWR



Stream Data Source: AGFD, 1993 & 1997

Figure 6.2-5
Grand Wash Basin
Perennial/Intermittent Streams and Major (>10 gpm) Springs

6.2.6 Groundwater Conditions of the Grand Wash Basin

Major aquifers, well yields, number of index wells and date of last water-level sweep are shown in Table 6.2-6. Figure 6.2-6 shows water-level change between 1990-1991 and 2003-2004. Figure 6.2-7 contains hydrographs for selected wells shown on Figure 6.2-6. Figure 6.2-8 shows well yield for one well. A description of aquifer data sources and methods is found in Volume 1, Section 1.3.2. A description of well data sources and methods, including water-level changes and well yields, is found in Volume 1, Section 1.3.19.

Major Aquifers

- Refer to Table 6.2-6 and Figure 6.2-6.
- Major aquifers in the basin include recent stream alluvium and sedimentary rock (Cottonwood Wash and Muddy Creek Formations).
- Most of the basin geology consists of consolidated crystalline and sedimentary rock.
- Data on groundwater flow direction is not available for this basin.

Well Yields

- Refer to Table 6.2-6 and Figure 6.2-8.
- As shown on Figure 6.2-8 well yield data are only available for one well, which yields less than 100 gallons per minute (gpm).

Water Level

- Refer to Figure 6.2-6. Water levels are shown for wells measured in 2003-2004.
- The Department annually measures two index wells in this basin. The water level in one well was at a depth of 21 feet and rose by more than 30 feet between 1990-1991 and 2003-2004. Water level in the other well is at a depth of 508 feet and was generally stable between 1990-1991 and 2003-2004.
- Hydrographs corresponding to the two wells found on Figure 6.2-6, but covering a longer time period are shown in Figure 6.2-7.

Table 6.2-6 Groundwater Data for the Grand Wash Basin

Basin Area, in square miles:	959	
Major Aquifer(s):	**Name and/or Geologic Units**	
	Recent Stream Alluvium	
	Basin Fill with Interbedded Volcanic Rock	
	Sedimentary Rock (Cottonwood Wash Formation)	
	Sedimentary Rock (Muddy Creek Formation)	
Well Yields, in gal/min:	N/A	Measured by ADWR and/or USGS
	10 (1 well reported)	Reported on registration forms for large (> 10-inch) diameter wells
	300	ADWR (1990)
	Range 0-500	USGS (1994)
Estimated Natural Recharge, in acre-feet/year:	N/A	
Estimated Water Currently in Storage, in acre-feet:	N/A	ADWR (1990 and 1994)
	N/A	Arizona Water Commission (1975)
Current Number of Index Wells:	2	
Date of Last Water-level Sweep:	1976 (6 wells measured)	

N/A = Not Available

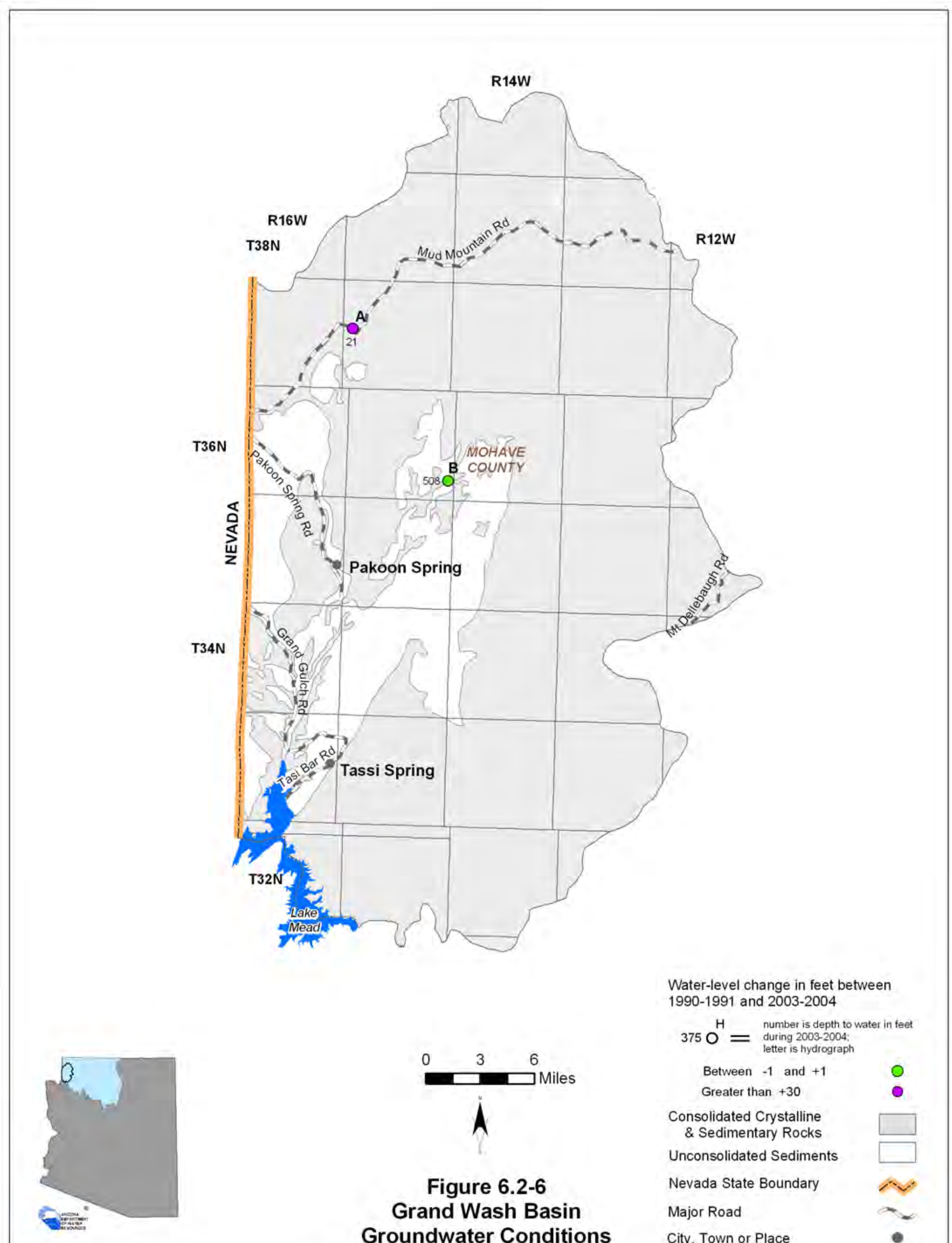
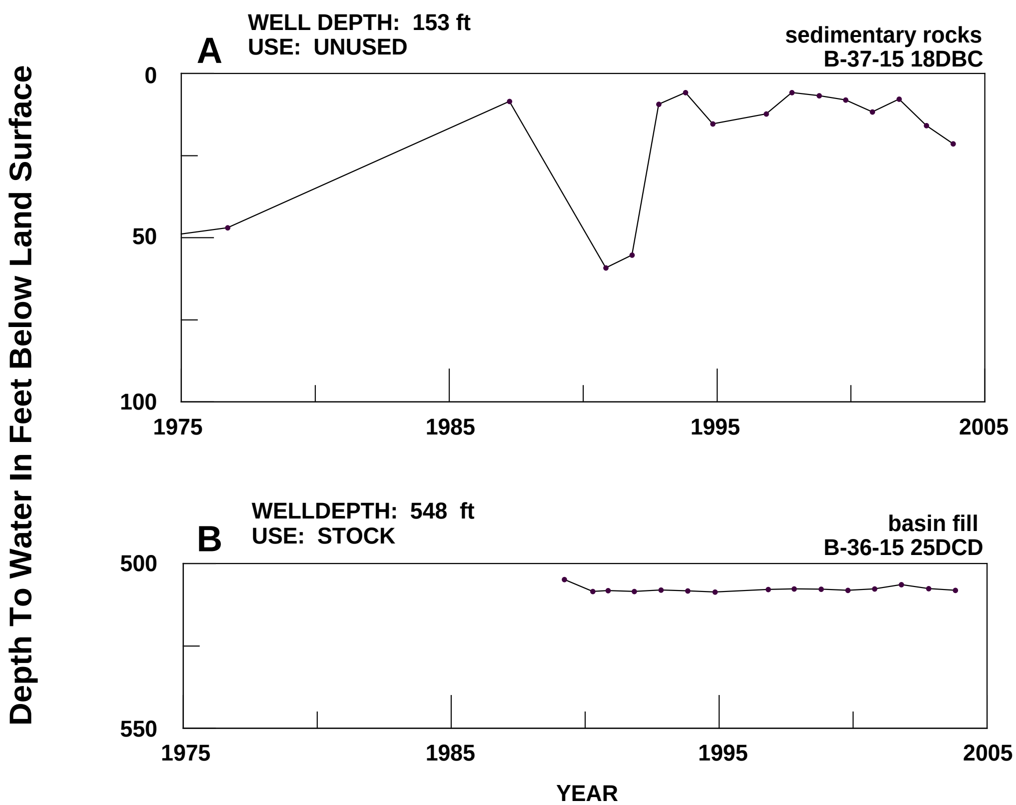


Figure 6.2-6
Grand Wash Basin
Groundwater Conditions

Figure 6.2-7
Grand Wash Basin
Hydrographs Showing Depth to Water in Selected Wells



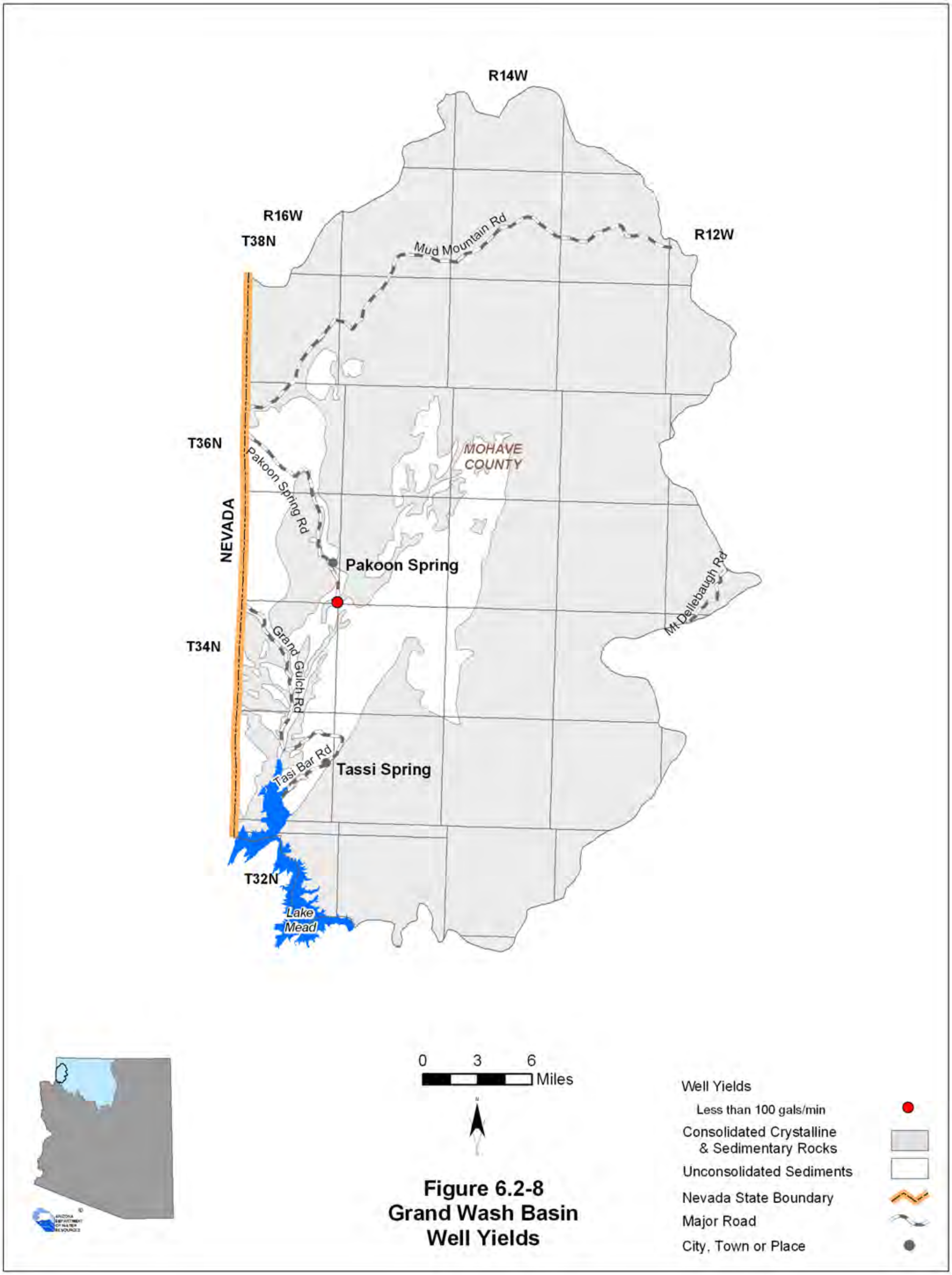


Figure 6.2-8
Grand Wash Basin
Well Yields

6.2.7 Water Quality of the Grand Wash Basin

Wells, springs and mine sites with parameter concentrations that have equaled or exceeded drinking water standard(s), including location and parameter(s) are shown in Table 6.2-7A. There are no impaired lakes and streams in this basin. Figure 6.2-9 shows the location of water quality occurrences keyed to Table 6.2-7. A description of water quality data sources and methods is found in Volume 1, Section 1.3.18. Not all parameters were measured at all sites; selective sampling for particular constituents is common.

Wells, Springs and Mines

- Refer to Table 6.2-7A.
- All seven springs have parameter concentrations of total dissolved solids that have equaled or exceeded drinking water standards.

Table 6.2-7 Water Quality Exceedences in the Grand Wash Basin[1]

A. Wells, Springs and Mines

Map Key	Site Type	Site Location			Parameter(s) Concentration has Equaled or Exceeded Drinking Water Standard (DWS)[2]
		Township	Range	Section	
1	Spring	38 North	14 West	14	TDS
2	Spring	33 North	15 West	8	TDS
3	Spring	33 North	15 West	9	TDS
4	Spring	33 North	15 West	9	TDS
5	Spring	33 North	15 West	18	TDS
6	Spring	33 North	16 West	3	TDS
7	Spring	33 North	16 West	4	TDS

B. Lakes and Streams

Map Key	Site Type	Site Name	Length of Impaired Stream Reach (in miles)	Area of Impaired Lake (in acres)	Designated Use Standard	Parameter(s) Exceeding Use Standard
None identified by ADWR at this time						

Notes:

[1] Water quality samples collected between 1980 and 2000.

[2] TDS = Total Dissolved Solids

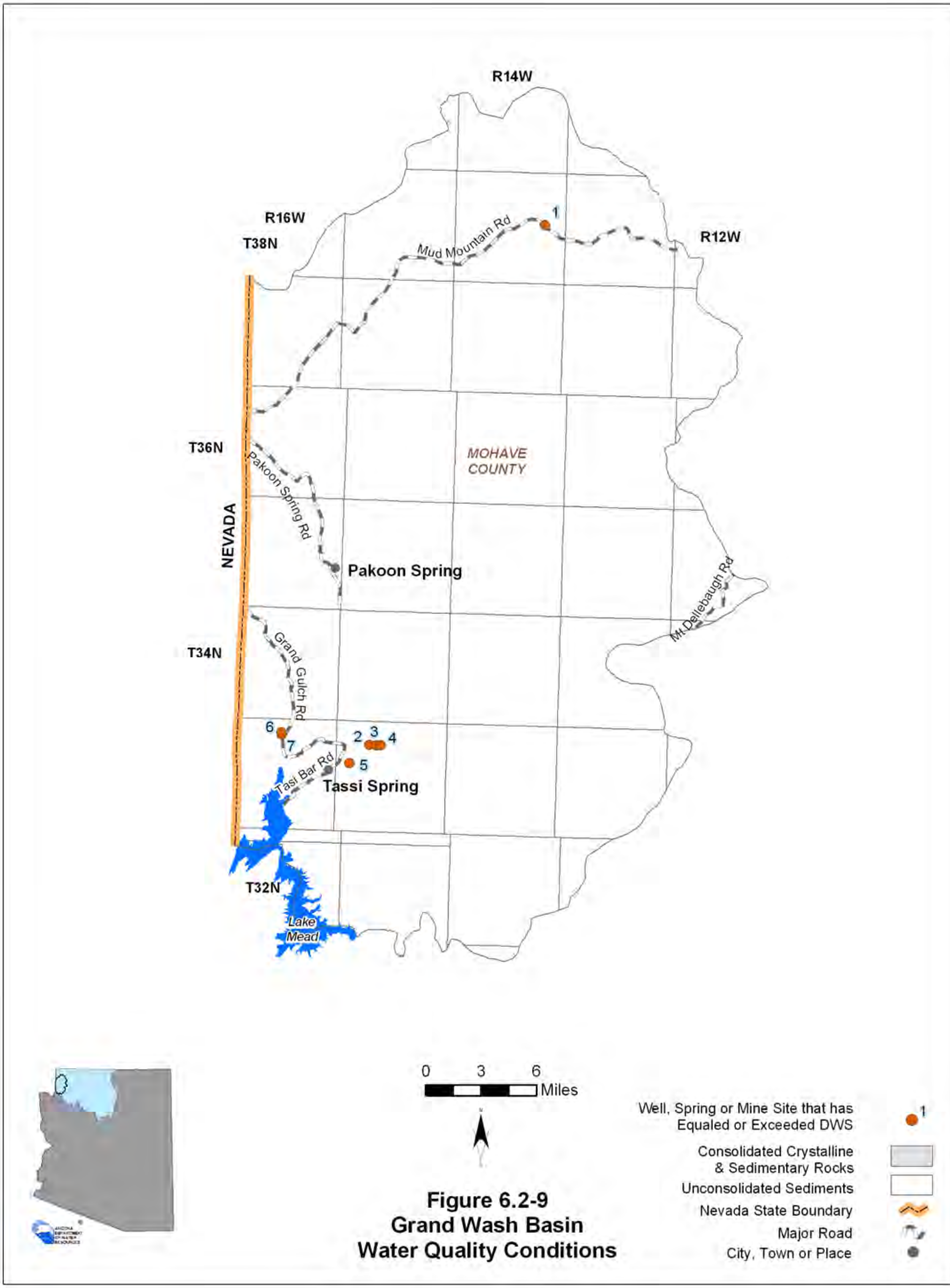


Figure 6.2-9
Grand Wash Basin
Water Quality Conditions

6.2.8 Cultural Water Demands in the Grand Wash Basin

Cultural water demand data including population, number of wells and the average well pumpage and surface water diversions by the municipal, industrial and agricultural sectors are shown in Table 6.2-8. There is no recorded effluent generation in this basin. The USGS National Gap Analysis Program, the primary source of cultural demand map data, showed no demand centers for this basin. A description of cultural water demand data sources and methods is found in Volume 1, Section 1.3.5. More detailed information on cultural water demands is found in Section 5.0.7.

Cultural Water Demands

- Refer to Table 6.2-8
- Population in this basin is very small, with 15 residents in 2000. Projections suggest a small increase in population through 2050.
- There are no recorded surface water uses in this basin. All groundwater use is for municipal demand and has remained relatively constant since 1971.
- As of 2003 there were 12 registered wells with a pumping capacity of less than or equal to 35 gallons per minute and no wells with a pumping capacity of more than 35 gallons per minute.

Table 6.2-8 Cultural Water Demands in the Grand Wash Basin[1]

Year	Recent (Census) and Projected (DES) Population	Number of Registered Water Supply Wells Drilled		Average Annual Demand (in acre-feet)						
				Well Pumpage			Surface-Water Diversions			Data Source
		Q ≤ 35 gpm	Q > 35 gpm	Municipal	Industrial	Irrigation	Municipal	Industrial	Irrigation	
1971										
1972										
1973				<500			NR			
1974										
1975										
1976		9[2]	0[2]							
1977										
1978				<500			NR			
1979										
1980	10									ADWR
1981	10									(1994)
1982	10									
1983	11	0	0	<500			NR			
1984	11									
1985	11									
1986	11									
1987	11									
1988	12	0	0	<500			NR			
1989	12									
1990	12									
1991	12									
1992	13									
1993	13	2	0	<300	NR	NR	NR			
1994	13									
1995	14									
1996	14									USGS
1997	14									(2005)
1998	14	1	0	<300	NR	NR	NR			
1999	15									
2000	15									
2001	15									
2002	16	0	0	<300	NR	NR	NR			
2003	16									
2010	19									
2020	23									
2030	29									
2040	37									
2050	46									
	WELL TOTALS:	**12**	**0**							

[1] Does not include evaporation losses from stockponds and reservoirs.
[2] Includes all wells through 1980.
NR - Not reported

Table 6.2-9 Effluent Generation in the Grand Wash Basin

Facility Name	Ownership	City/Location Served	Population Served	Volume Treated/Generated (acre-feet)	Disposal Method								Current Treatment Level	Population Not Served	Year of Record
					Water-course	Evaporation Pond	Irrigation	Golf Course	Municipal Reuse	Wildlife Area	Discharged to Another Facility	Infiltration Basins			
No Wastewater Treatment Facilities Identified by ADWR in the Basin															

6.2.9 Water Adequacy Determinations in the Grand Wash Basin

There are no water adequacy applications on file with the Department as of May, 2005 for the Grand Wash Basin. A description of the Water Adequacy Program is found in Volume 1, Appendix A. Adequacy determination data sources and methods are found in Volume 1, Section 1.3.1.

Table 6.2-10. Adequacy Determinations in the Grand Wash Basin

Map Key	Subdivision Name	County	Location			No. of Lots	ADWR File No.	ADWR Adequacy Determination	Reason(s) for Inadequacy Determination	Date of Determination	Water Provider at the Time of Application
			Township	Range	Section						
None identified by ADWR at this time											

Grand Wash Basin

References and Supplemental Reading

References

A

Arizona Corporation Commission (ACC), 2005, Annual reports, Private Sewer companies, 1990 to 2005: ACC Utilities Division.

_____, 2005, Annual reports, Small water providers, 1990 to 2005: ACC Utilities Division.

Arizona Crop and Livestock Reporting Service, 1973, 1972 Arizona Agricultural Statistics: Bulletin S-8.

Arizona Department of Economic Security (DES), 2005, Workforce Informer: Data file, accessed August 2005, http://www.workforce.az.gov.*

Arizona Department of Environmental Quality, 2005, Active dairy farms & feedlots: Data file, received October 2005.

_____, 2005, ADEQSWI: Data file, received September 2005.

_____, 2005, ADEQWATP: Data file, received May 2005.

_____, 2005, ADEQWWTP: Data file, received August 2005.

_____, 2005, Azurite: Data file, received September 2005.

_____, 2005, Effluent dependent waters: GIS cover, received December 2005.*

_____, 2005, Impaired lakes and reaches: GIS cover, received January 2006.

_____, 2005, Surface water sources used by water providers: Data file, received June 2005.

_____, 2005, WWTP and permit files: Miscellaneous working files, received July 2005.

_____, 2004, Water providers with arsenic concentrations in wells over 10ppb: Data file, received August 2004.

_____, 2004, Water quality exceedences by watershed: Data file, received June 2004.

_____, 2004, Water quality exceedences for drinking water providers in Arizona: Data file, received September 2004.*

Arizona Department of Mines and Mineral Resources (ADMMR), 2005, Active mines in Arizona: Database, accessed at http:// www.admmr.state.az.us.

Arizona Department of Water Resources (ADWR), 2006, Assured and adequate water supply applications: Project files, ADWR Hydrology Division.

_____, 2005, Agricultural Surface Water Use Estimates: Unpublished analysis, ADWR Office of Resource Assessment Planning.

_____, 2005, Automated recorder sites: Data files, ADWR Basic Data Unit.*

_____, 2005, 2004 rural water provider questionnaire: Data files, ADWR Office of Resource Assessment Planning.*

_____, 2005, Assured and adequate water supply determinations: Database, ADWR Office of Assured and Adequate Water Supply.

______, 2005, Flood warning gages: Database, ADWR Office of Water Engineering.

______, 2005, Inspected dams: Database, ADWR Office of Dam Safety.

______, 2005, Non-jurisdictional dams: Database, ADWR Office of Dam Safety.

______, 2005, Groundwater Site Inventory (GWSI): Database, ADWR Hydrology Division.*

______, 2005, Registry of surface water rights: ADWR Office of Water Management.*

_______, 2005, Water Protection Fund: Database, ADWR Office of Drought, Conservation and Riparian Planning.
_______, Water use by golf courses in rural Arizona: Unpublished analysis, ADWR Office of Regional Strategic Planning.
_______, 2005, Wells55: Database.*
_______, 2002, Groundwater quality exceedences in rural Arizona from 1975 to 2001: Data file, ADWR Office of Regional Strategic Planning.*
_______, 1994, Arizona Water Resources Assessment, Vol. I, Inventory and Analysis.*
_______, 1994, Arizona Water Resources Assessment, Vol. II, Hydrologic Summary.*
_______, 1990, Draft outline of basin profiles for the state water assessment: ADWR Statewide Planning Division, Memorandum to L. Linser, D.W., January, 16, 1990.*
Arizona Game and Fish Department, 2005, Arizona Waterways: Data file, received April 2005.
Arizona Game & Fish Department (AGF), 1997 & 1993, Statewide riparian inventory and mapping project: GIS cover.
______, 1982, Arizona Lakes Classification Study.
Arizona Land Resource Information System (ALRIS), 2005, Springs: GIS cover, accessed January 2006 at http://www.land.state.az.us/alris/index.html.*
______, 2005, Streams: GIS cover, accessed 2005 at http://www.land.state.az.us /alris/index.html.*
______, 2005, Water features: GIS cover, accessed July 2005 at http://www.land.state.az. us/alris/index.html.*
______, 2004, Land ownership: GIS cover, accessed in 2004 at http://www.land.state.az.us /alris/index.html.*
Arizona Meteorological Network (AZMET), 2005, Arizona climate stations: Pan evaporation data, accessed December 2005 at http://www.ag.arizona.edu /azmet/locate.html.
Arizona Water Commission, 1975, Summary, Phase I, Arizona State Water Plan, Inventory of resource and uses.

D

Diroll, M., and Marsh, D., 2006, Status of water quality in Arizona-2004 integrated 305(b) assessment and 303(d) listing report: ADEQ report.*

E

Environmental Protection Agency (EPA), 2005, Surf Your Watershed: Facility reports, accessed April 2005 at http://oaspub.epa.gov/enviro/ef_home2.water.*
______, 2005, 2000 and 1996, Clean Watershed Needs Survey: datasets, accessed March 2005 at http://www.epa.gov/owm/mtb/cwns/index.htm.*

F

Fisk, G.G., Duet, D.W., Evans, C.E., Angernoth, N.K., and Longsworth, S.A., 2004, Water Resources Data, Arizona Water Year 2003: USGS Water-Data Report AZ-03-1.*

G

Grand Canyon Wildlands Council, 2002, Arizona Strip Springs, Seeps and Natural Ponds: Inventory, Assessment and Development of Recovery Priorities: AZ Water Protection

Fund 99-074.*

K

Konieczki, A.D. and Wilson, R.P., 1992, Annual summary of ground-water conditions in Arizona, spring 1986 to spring 1987: USGS Open File Report 92-54.*

M

McCormack, H.F., Fisk, G.G., Duet, N.R., Evans, D.W., Roberts, W.P., and Castillo, N.K., 2002, Water resources data Arizona, water year 2002: USGS Water Data Report AZ-02-1.*

N

Natural Resources Conservation Service (NRCS), 2005, SNOTEL (Snowpack Telemetry) stations: Data file, accessed December 2005 at http://www3.wcc.nrcs.usda. gov/nwcc/ sntlsites.jsp?state=AZ.

_______, 2005, Snow Course stations: Data file, accessed December 2005 at http://www.wcc.nrcs. usda.gov/nwcc/snow-course-sites.jsp?state=AZ

O

Oregon State University, Spatial Climate Analysis Service (SCAS), 2006, Average annual precipitation in Arizona for 1961-1990: PRISM GIS cover, accessed in 2006 at www.ocs. orst.edu/prism.*

P

Pope, G.L., Rigas, P.D., and Smith, C.F., 1998, Statistical summaries of streamflow data and characteristics of drainage basins for selected streamflow-gaging stations in Arizona through water year 1996: USGS Water Resources Investigations Report 98-4225.*

T

Tadayon, S., 2004, Water withdrawals for irrigation, municipal, mining, thermoelectric-power, and drainage uses in Arizona outside of the active management areas, 1991-2000: USGS Scientific Investigations Report 2004-5293, 27 pp.*

U

US Army Corps of Engineers, 2004 and 2005, National Inventory of Dams: Arizona Dataset, accessed November 2004 to April 2005 at http://crunch.tec.army.mil /nid/ webpages/nid.cfm

US Geological Survey (USGS), 2006, Average annual runoff in the United States, 1951-1980: Data file, accessed March 2006 at http://aa179.cr.usgs.gov/metadata /wrdmeta/runoff. htm.*

_____, 2006, Springs and spring discharges: Dataset, received November 2004 and January 2006 from USGS office in Tucson, AZ.*

_____, 2006, National Hydrography Dataset: Arizona dataset, accessed at http://nhd.usgs. gov/.*

_____, 2005, National Water Information System (NWIS): Arizona dataset, accessed December 2005 at http://waterdata.usgs.gov/nwis.*

_____, 2004, Southwest Regional Gap analysis study- land cover descriptions: Electronic file, accessed January 2005 at http://earth.gis.usu.edu/swgap.*

_____, 1981, Geographic digital data for 1:500,000 scale maps: USGS National Mapping Program Data Users Guide.*

V

Valencia, R.A., Wennerlund, J.A., Winstead, R.A., Woods, S., Riley, L., Swanson, E., and Olson, S., 1993, Arizona riparian inventory and mapping project: Arizona Game and Fish Department.

W

Wahl, C.R., Boe, S.R., Wennerlund, R.A., Winstead, R.A., Allison, L.J., Kubly, D.M., 1997, Remote sensing mapping of Arizona intermittent stream riparian areas: Arizona Game and Fish Technical Report 112.

Water Infrastructure Finance Authority of Arizona (WIFA), 2005, Clean Watershed Needs Survey-2004: Unpublished data sheets, received July 2005.

Western Regional Climate Center (WRCC), 2005, Pan evaporation stations: Data file accessed December 2005 at http://www4.ncdc.noaa.gov/cgi-win/wwcgi.dll?wwDI~GetCity~USA.

_____, 2005, Precipitation and temperature stations: Data file, accessed December 2005 at http://www4.ncdc.noaa.gov/cgi-win/wwcgi.dll?wwDI~GetCity~USA.

Wilson, R.P., 1992, Summary of groundwater conditions in Arizona 1985 to 1986: USGS Water Resources Investigation Report, 90-4179.*

*All references marked with an asterisk contain information that was directly used in the basin summaries, tables or maps.

Supplemental Reading

Andersen, Mark, 2005, Assessment of water availability in the Lower Colorado River basin: in Conservation and Innovation in Water Management: Proceedings of the 18th annual Arizona Hydrological Society Symposium, Flagstaff, Arizona, September, 2005.

Bales, J.T., and Laney, R.L., 1992, Geohydrologic reconnaissance of Lake Mead National Recreation area: Virgin River, Nevada to Grand Wash Cliffs, Arizona: USGS Water Resources Investigations Report 91-4185, 29 p.

Billingsley, G.H., Beard, S.B, Priest, S.S., Wellmeyer, J.L, Block, D.L., 2004, Geologic Map of the Lower Grand Wash Cliffs and Vicinity, Mohave County, Northwestern Arizona. Miscellaneous Field Studies Map MF-2427

Bureau of Reclamation, 2002, Grand Canyon National Park water supply appraisal study, Coconino, Mohave and Yavapai Counties, Arizona: Grand Canyon National Park report.

Bureau of Land Management, 2005, Draft resource management plan and draft Environmental Impact Statement for Vermillion Cliffs National Monument, and the Grand Canyon Parashant National Monument: BLM Arizona Field Office and NPS joint report, 2005.

Dettiger, M., Harrill, J., Schmidt, D., 1995, Distribution of carbonite rock aquifers and the potential for their development, southern Nevada and adjacent parts of California , Arizona and Utah: USGS Water Resources Investigations Report 91-4146, 100 p.

Enzel, Y., Ely, L.L., House, P.K., Baker, V.R., and Webb, R.H., 1993, Paleoflood evidence for a natural upper bound to flood magnitudes in the Colorado River Basin: Water Resources Research, vol. 29, no. 7, p. 2287-2297.

Freilich, Leitner & Carlisle, 2005, Mohave County General Plan: Water Resources Element.

Gauger, R.W., 1997, River-stage data Colorado River, Glen Canyon Dam to upper Lake Mead, Arizona, 1990-1994: USGS Open – File Report 96-626, 20 p.

Hart, R.J., 1999, Water Quality of the Colorado River monitored by the USGS National Stream Quality Accounting Network: in Water Issues and Partnerships for Rural Arizona: Proceedings of the 12 annual symposium of the Arizona Hydrological Society, September 1999, Hon Dah, Arizona.

Hereford, R., Webb, G., and Graham, S., 2002, Precipitation history of the Colorado Plateau region, 1990 – 2000: USGS Fact sheet 119-02.

Smith J.D., Wiele, S., 1991, Flow and sediment transport in the Colorado River between Lake Powell and Lake Mead: USGS report 38 p.

Rote, J.J., Flynn, M.E., and Bills, D.J., 1997, Hydrologic data, Colorado River and major tributaries, Glen Canyon Dam to Diamond Creek, Arizona, water years 1990-1995: USGS Open–File Report 97-250, 474 p.

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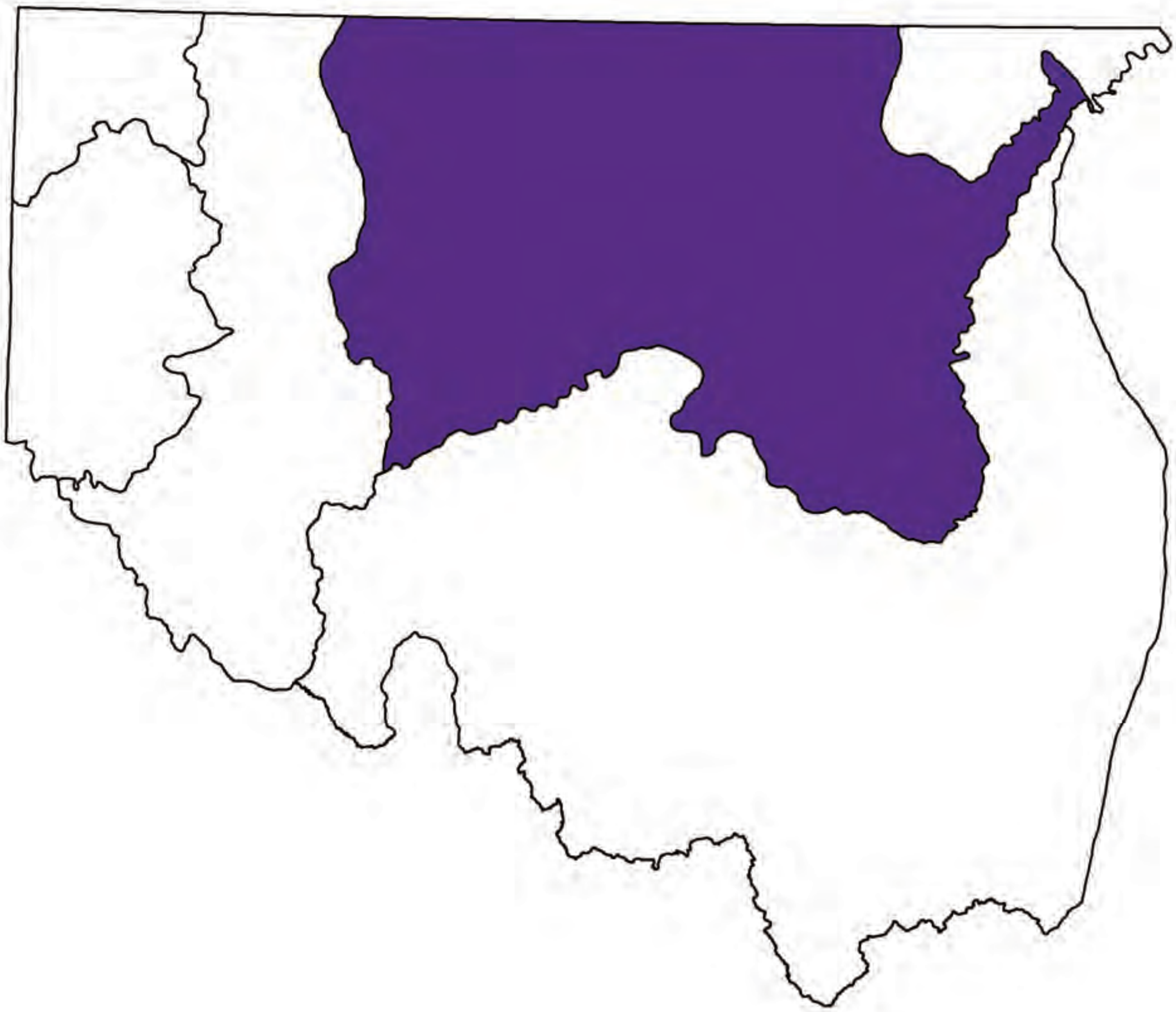
Section 6.3
Kanab Plateau Basin



6.3.1 Geography of the Kanab Plateau Basin

The Kanab Plateau Basin, located in the west central part of the planning area is 4,247 square miles in area. Geographic features and principal communities are shown on Figure 6.3-1. The basin is characterized by plateaus and canyons. Vegetation types include Mohave and Great Basin desertscrub, plains grasslands, Great Basin conifer woodland, Great Basin subalpine conifer forest and Rocky Mountain montane conifer forest. There are small areas of subalpine grassland on the Kaibab Plateau north of the North Rim, generally along Highway 67. (See Figure 6.0-9)

- Principal geographic features shown on Figure 6.3-1 are:
    - Principal basin communities of Colorado City, Fredonia, Kaibab and Moccasin
    - Other communities and places of Jacob Lake, Lees Ferry, Marble Canyon, North Rim and Toroweap Ranger Station
    - The Colorado River and Grand Canyon forming the southern basin boundary
    - A series of plateaus running north-south; the Kaibab, Kanab and Uinkaret Plateaus
    - Vermillion Cliffs in the northeast portion of the basin
    - Granite Gorge on the southeastern basin boundary
    - Antelope Valley between the Uinkaret and Kanab Plateaus
    - Point Imperial, the highest point in the basin at 8,803 feet, located east of the North Rim
- Not well shown on Figure 6.3-1 are the Hurricane Cliffs on the northwestern basin boundary and Marble Canyon on the eastern basin boundary.

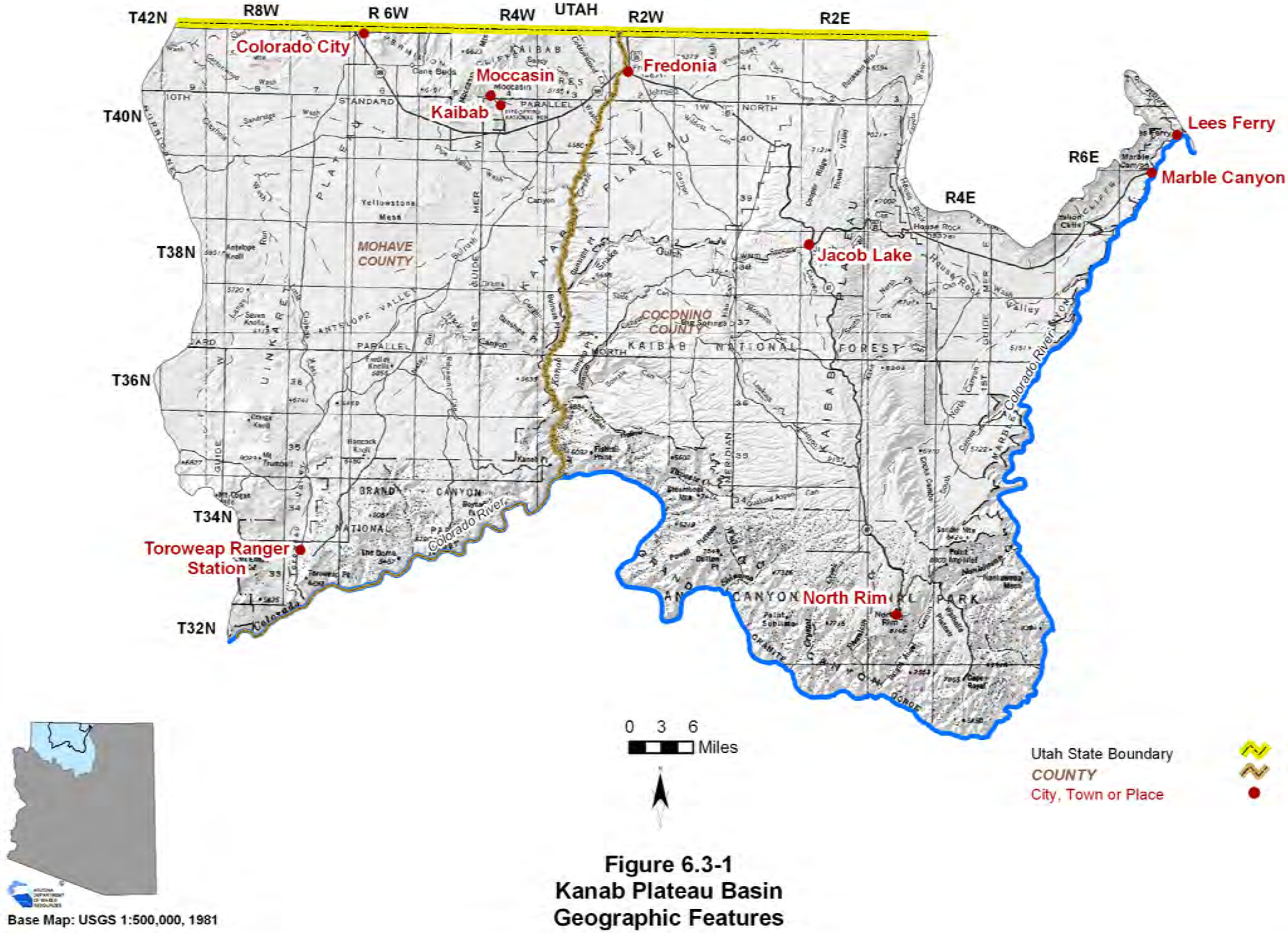


Figure 6.3-1
Kanab Plateau Basin
Geographic Features

6.3.2 Land Ownership in the Kanab Plateau Basin

Land ownership, including the percentage of ownership by category, for the Kanab Plateau Basin is shown in Figure 6.3-2. Principal features of land ownership in this basin are the large parcels of U.S. Bureau of Land Management (BLM), National Forest Service and National Park Service (NPS) lands. Three percent is managed as the Vermillion Cliffs National Monument by the BLM and 2% is managed as the Grand Canyon-Parashant National Monument by the BLM and NPS. A description of land ownership data sources and methods is found in Volume 1, Section 1.3.8. Land ownership categories are discussed below in the order of percentage from largest to smallest in the basin.

U.S. Bureau of Land Management (BLM)
- 41.6% of the land is federally owned and managed by the Arizona Strip Field Office of the Bureau of Land Management.
- BLM land in the basin includes portions of the Grand Canyon-Parashant and Vermilion Cliffs National Monuments as well as the 7,880 acre Mt. Trumbull Wilderness, 6,860 acre Cottonwood Point Wilderness and a portion of the 79,000 acre Paria Canyon Wilderness.
- Land uses include grazing, recreation and resource conservation.

National Forest and Wilderness
- 24.1% of the land is federally owned and managed as National Forest and Wilderness.
- Forest lands are part of the Kaibab National Forest and include the 40,610-acre Saddle Mountain Wilderness and the 68,340 acre Kanab Creek Wilderness.
- Land uses include recreation, resource conservation, grazing and timber production.

National Park Service (NPS)
- 22.2% of the land is federally owned and managed by the National Park Service.
- This basin includes portions of Grand Canyon National Park, Grand Canyon-Parashant National Monument and Glen Canyon National Recreation Area.
- Land uses include resource conservation and recreation.

Indian Reservation
- 4.4% of the land is under tribal ownership of the Kaibab-Paiute Indian Tribe.
- Land uses include domestic, commercial, agricultural and ranching.

State Trust Land
- 4.3% of the land is held in trust for the public schools under the State Trust Land system.
- State land is located throughout the basin interspersed with BLM and private land.
- Primary land use is grazing.

Private
- 3.4% of the land is private.
- The majority of the private land is in the northern portion of the basin in the vicinity of Colorado City and Fredonia.
- Land uses include domestic, commercial, agriculture and ranching.

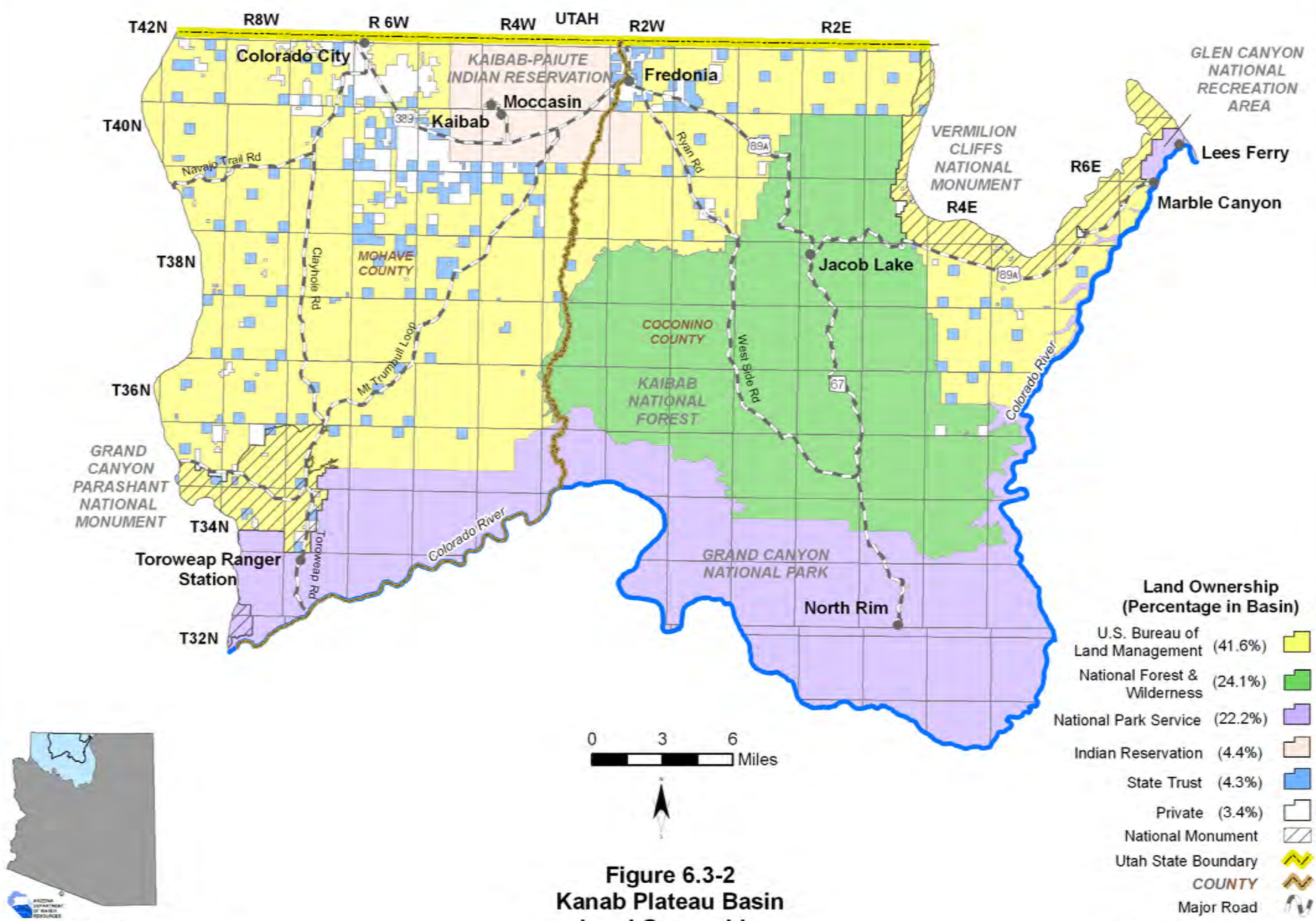


Figure 6.3-2
Kanab Plateau Basin
Land Ownership

Source: ALRIS, 2004
Bureau of Land management, 1999 & 2000

6.3.3 Climate of the Kanab Plateau Basin

Climate data from NOAA/NWS Co-op Network and SNOTEL/Snowcourse stations are complied in Table 6.3-1 and the locations are shown on Figure 6.3-3. Figure 6.3-3 also shows precipitation contour data from the Spatial Climate Analysis Service (SCAS) at Oregon State University. The Kanab Plateau Basin does not contain Evaporation Pan or AZMET stations. A description of the climate data sources and methods is found in Volume 1, Section 1.3.3.

NOAA/NWS Co-op Network

- Refer to Table 6.3-1A
- Temperatures at the nine NOAA/NWS Co-op Network stations range from an average annual high of 91.4°F at Phantom Ranch to an average annual low of 23.2°F at Colorado City.
- Most stations report highest average seasonal rainfall in the summer season (July-September) when about 30% of the annual rainfall occurs.
- The highest average annual precipitation is 25.70 inches at Bright Angel Ranger Station and the lowest average annual precipitation is 6.55 inches at Lees Ferry.

SNOTEL/Snowcourse

- Refer to Table 6.3-1D
- There is one SNOTEL/Snowcourse station in the basin located at the North Rim of the Grand Canyon.
- The highest average monthly snowpack is usually in March with an average of 9.9 inches of snowpack.

SCAS Precipitation Data

- See Figure 6.1-3
- Additional precipitation data shows average annual rainfall as high as 30 inches north of the North Rim and as low as four inches along the Colorado River.

Table 6.3-1 Climate Data for the Kanab Plateau Basin

A. NOAA/NWS Co-op Network:

Station Name	Elevation (in feet)	Period of Record Used for Averages	Average Temperature Range (in F)		Average Precipitation (in inches)				
			Max/Month	Min/Month	Winter	Spring	Summer	Fall	Annual
Bright Angel Ranger Station	8,400	1971-2000	61.8/Jul	27.2/Jan	10.79	2.80	5.76	6.35	25.70
Colorado City	5,010	1971-2000	76.8/Jul	23.2/Jan, Dec	4.41	2.70	4.04	3.02	14.17
Fredonia	4,680	1948-2005[1]	74.2/Jul	32.4/Jan	2.79	1.40	2.79	3.34	10.32
Inner Canyon USGS	2,570	1948-1966	91.5/Jul	45.8/Jan	2.13	1.23	3.21	1.82	8.38
Jacob Lake	7,830	1950-1987[1]	64.9/Jul	27.9/Jan	5.71	3.64	7.08	6.67	23.10
Lees Ferry	3,210	1971-2000	87.3/Jul	37.8/Jan, Dec	1.64	0.91	2.33	1.67	6.55
Phantom Ranch	2,570	1971-2000	91.4/Jul	47.0/Jan	3.12	1.09	3.13	2.43	9.77
Pipe Springs National Monument	4,920	1971-2000	76.7/Jul	34.8/Jan	3.81	1.59	3.30	2.56	11.26
Tuweep	4,780	1948-1985[1]	79.6/Jul	38.5/Jan	3.93	1.46	3.97	2.98	12.34

Source: WRCC, 2003
Notes:
[1] Average temperature for period of record shown; average precipitation from 1971-2000

B. Evaporation Pan:

Station Name	Elevation (in feet)	Period of Record Used for Averages	Avg. Annual Evap (in inches)
None			

Source: WRCC, 2003.

C. AZMET:

Station Name	Elevation (in feet)	Period of Record Used for Averages	Average Annual Reference Evaportranspiration, in inches (*Number of years to calculate averages*)
None			

Source: Arizona Meteorological Network, 2005

D. SNOTEL/Snowcourse:

Station Name	Elevation (in feet)	Period of Record Used for Averages	Average Snowpack, as Snow Water Content, at the Beginning of the Month, in Inches (*Number of measurements to calculate average*)					
			Jan.	Feb.	March	April	May	June
Bright Angel	8,400	1947 - current	3.4*(26)*	*6.9(48)*	*9.9(47)*	9.0*(42)*	16.2*(1)*	0*(0)*

Source: NRCS, 2005

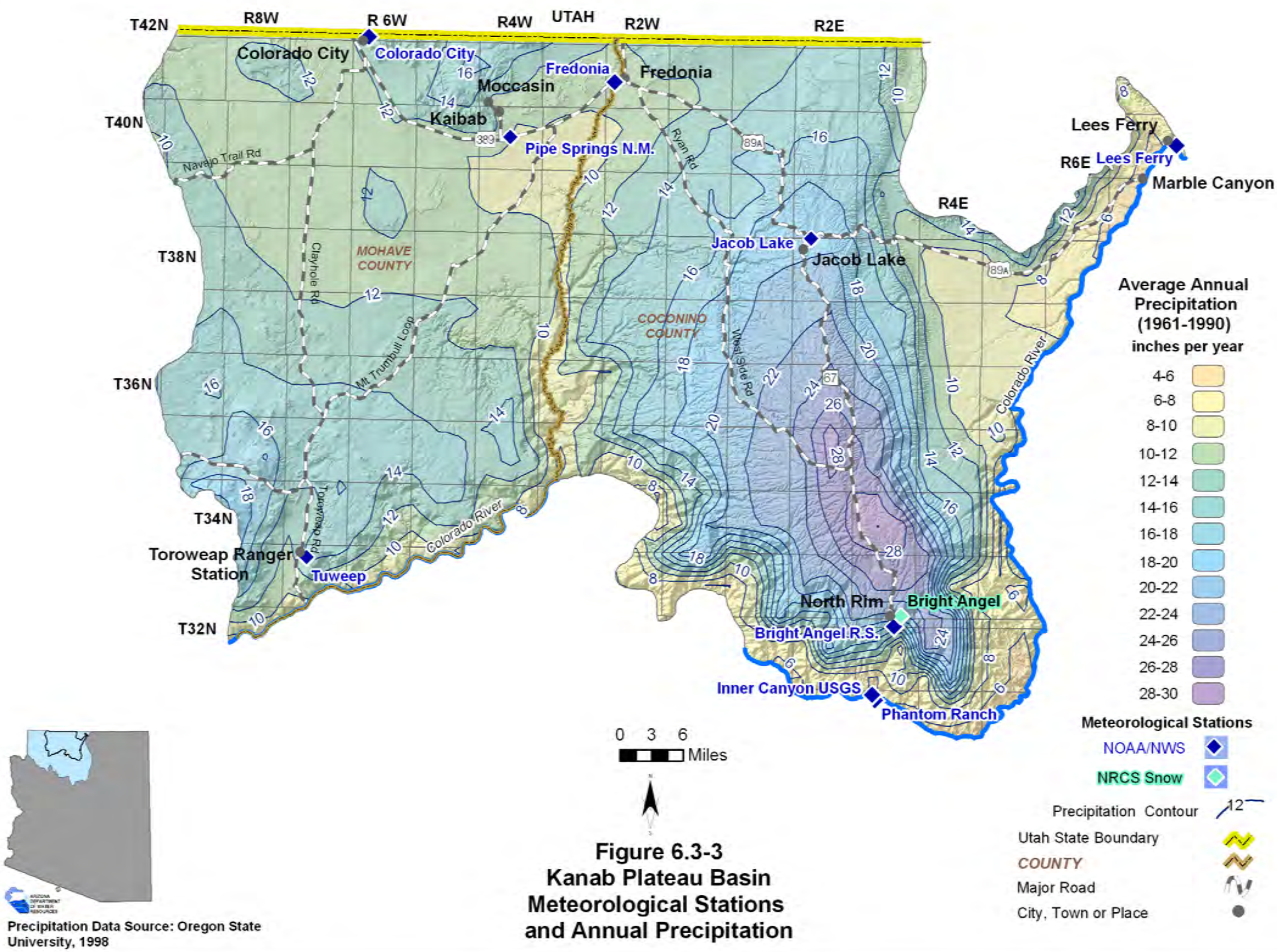


Figure 6.3-3
Kanab Plateau Basin
Meteorological Stations
and Annual Precipitation

6.3.4 Surface Water Conditions in the Kanab Plateau Basin

Streamflow data, including average seasonal flow, average annual flow and other information are shown in Table 6.3-2. Flood ALERT equipment in the basin is shown in Table 6.3-3. Reservoir and stockpond data, including maximum storage or maximum surface area, are shown in Table 6.3-4. The location of streamflow gages identified by USGS number, flood ALERT equipment, USGS runoff contours and large reservoirs are shown on Figure 6.3-5. A description of stream data sources and methods is found in Volume 1, Section 1.3.16. A description of reservoir data sources and methods is found in Volume 1, Section 1.3.11. A description of stockpond data sources and methods is found in Volume 1, Section 1.3.15.

Streamflow Data

- Refer to Table 6.3-2.
- Data from five stations located at three watercourses are shown in the table and their location is shown on Figure 6.3-4. One station has been discontinued and three stations are real-time stations.
- The Colorado River near Grand Canyon station receives highest seasonal flow in the spring (April-June) when 43% of the average annual flow occurs. Unlike the other two stations on the Colorado River in this basin, the period of record for this station predates Glen Canyon Dam upstream on the Colorado River, and therefore more closely reflects the river's unaltered average seasonal flow.
- The largest annual flow recorded in the basin is 20.6 million acre feet in 1984 at the Colorado River near Grand Canyon station with a contributing drainage area of 144,660 square miles.
- The Colorado River in the basin has a mean and median annual flow of over eight million acre-feet at all three gages. The Paria River is a major tributary to the Colorado River, with a median annual flow of over 18,000 acre-feet.
- Figure 6.3-4 shows the annual flow in the Colorado River near Grand Canyon station. Flood events/Glen Canyon Dam releases are shown in 1983-84 and in 1998. Otherwise the data show below average flow, and less variability in year-to-year flow after construction of Glen Canyon Dam in 1964. Note the very low flow in 1963-64 as the reservoir was being filled.

Flood ALERT Equipment

- Refer to Table 6.3-3.
- As of October 2005 there was one weather station in the basin located at Colorado City.

Reservoirs and Stockponds

- Refer to Table 6.3-4.
- The basin contains three large reservoirs. The largest is Fredonia, an intermittent lake, with a maximum storage capacity of 2,710 acre-feet.

- The reservoirs are used as flood control, for irrigation and for fire protection or as a stock or farm pond.
- Two of the three large reservoirs in this basin are dry or intermittent lakes.
- Surface water is stored or could be stored in ten small reservoirs.
- There are 705 registered stockponds in this basin.

Runoff Contour

- Refer to Figure 6.3-5.
- Average annual runoff is highest, two inches per year or 106 acre-feet per square mile, below the Kaibab Plateau in the western portion of the basin and decreases to 0.1 inches, or five acre-feet per square mile, east and west of the Kaibab Plateau.

Figure 6.3-4 Annual Flows (acre-feet) Colorado River near Grand Canyon 1923-2005 (Station # 9402500)

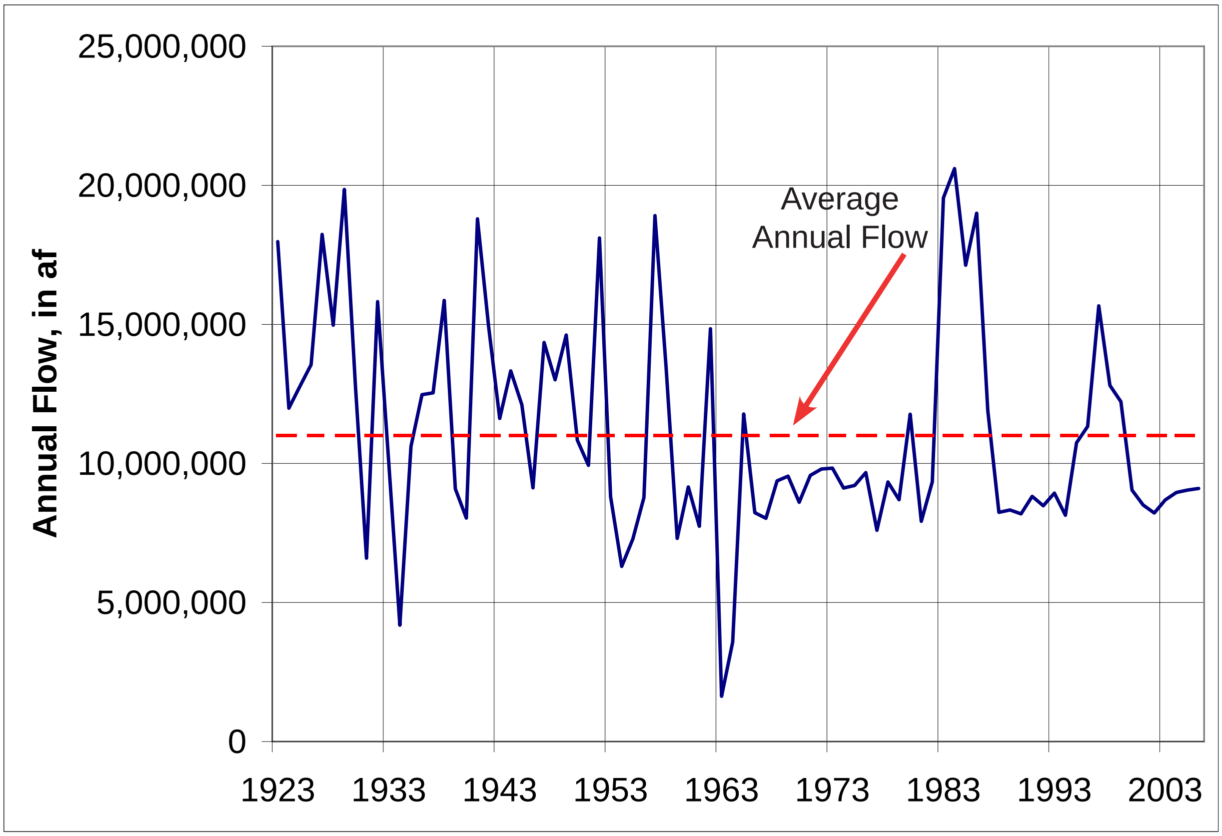


Table 6.3-2 Streamflow Data for the Kanab Plateau Basin

Station Number	USGS Station Name	Drainage Area (in mi^2)	Mean Basin Elevation (in feet)	Period of Record	Average Seasonal Flow (% of annual flow)				Annual Flow/Year (in acre-feet)				Years of Record
					Winter	Spring	Summer	Fall	Minimum	Median	Mean	Maximum	
9382000	Paria River at Lees Ferry	1,410	6,150	10/1923-current (real time)	29	11	38	22	9,052 (1977)	18,104	20,606	47,867 (1980)	79
9383000[1]	Colorado River at Compact Point near Lees Ferry	108,041	NA	10/1980-current	24	25	28	22	7,833,437 (1988)	8,383,659	9,876,067	18699615 (1986)	20
9383100	Colorado River above Little Colorado River near Desert View	114,272	NA	9/1989-9/2001 (discontinued)	25	25	27	23	8,188,186 (1990)	9,610,439	10,357,150	15,420,721 (1997)	10
9402500	Colorado River near Grand Canyon	137,641	NA	10/1922-current (real time)	17	43	24	16	1,629,360 (1963)	9,884,422	11,234,437	20,551,661 (1984)	79
9402501	Colorado River near Grand Canyon (Stonehouse)	NA	NA	11/2001-current	27	25	28	20	8,209,905 (2002)	8,466,917	8,466,917	8,723,929 (2003)	2
9403780	Kanab Creek near Fredonia	1,085	6,100	10/1963-9/1980 (discontinued)	40	27	20	14	608 (1964)	3,743	4,603	11,728 (1979)	16

Sources: USGS NWIS, USGS 1998 and USGS 2003.

Notes:
[1] This gage is also included in the Little Colorado River Basin. It is not an actual gage but a compilation of data from the Paria River gage 09392000 and the Lees Ferry gage 09380000 in the Little Colorado River Basin and is used for accounting purposes.
NA = Not available
Average seasonal flow and annual flow/year data are current as of water year 2003
Statistics based on Calendar Year
Annual Flow statistics based on monthly values
Summation of Average Annual Flows may not equal 100 due to rounding.
Period of record may not equal Year of Record used for annual Flow/Year statistics due to only using years with a 12 month record

Table 6.3-3 Flood ALERT Equipment in the Kanab Plateau Basin

Station ID	Station Name	Station Type	Install Date	Responsibility
7580	Colorado City	Weather Station	NA	Mohave County FCD

Notes:
FCD = Flood Control District
NA = Information is not available at this time

Table 6.3-4 Reservoirs and Stockponds in the Kanab Plateau Basin

A. Large Reservoirs (500 acre-feet capacity and greater)

MAP KEY	RESERVOIR/LAKE NAME *(Name of dam, if different)*	OWNER/OPERATOR	MAXIMUM STORAGE (AF)	USE[1]	JURISDICTION
1	Fredonia[2]	Fredonia	2,710	C	State

Source: U.S. Army Corps of Engineers 2005

B. Other Large Reservoirs (50 acre surface area or greater)[3]

MAP KEY	RESERVOIR/LAKE NAME *(Name of dam, if different)*	OWNER/OPERATOR	MAXIMUM SURFACE AREA (acres)	USE[1]	JURISDICTION
2	Lakes of Short Creek	Short Creek Southside Irrigation Co.	200	I	State
3	Toroweap[4]	National Park Service	83	P	Federal

C. Small Reservoirs (greater than 15 acre-feet and less than 500 acre-feet capacity)

Total number: 1
Total maximum storage: 104 acre-feet

D. Other Small Reservoirs (between 5 and 50 acres surface area)[3]

Total number: 9
Total surface area: 112 acres

E. Stockponds (up to 15 acre-feet capacity)

Total number: 705

[1] C=flood control; I=irrigation, P=fire protection, stock or farm pond
[2] Intermittent lake
[3] Capacity data not available to ADWR
[4] Dry lake

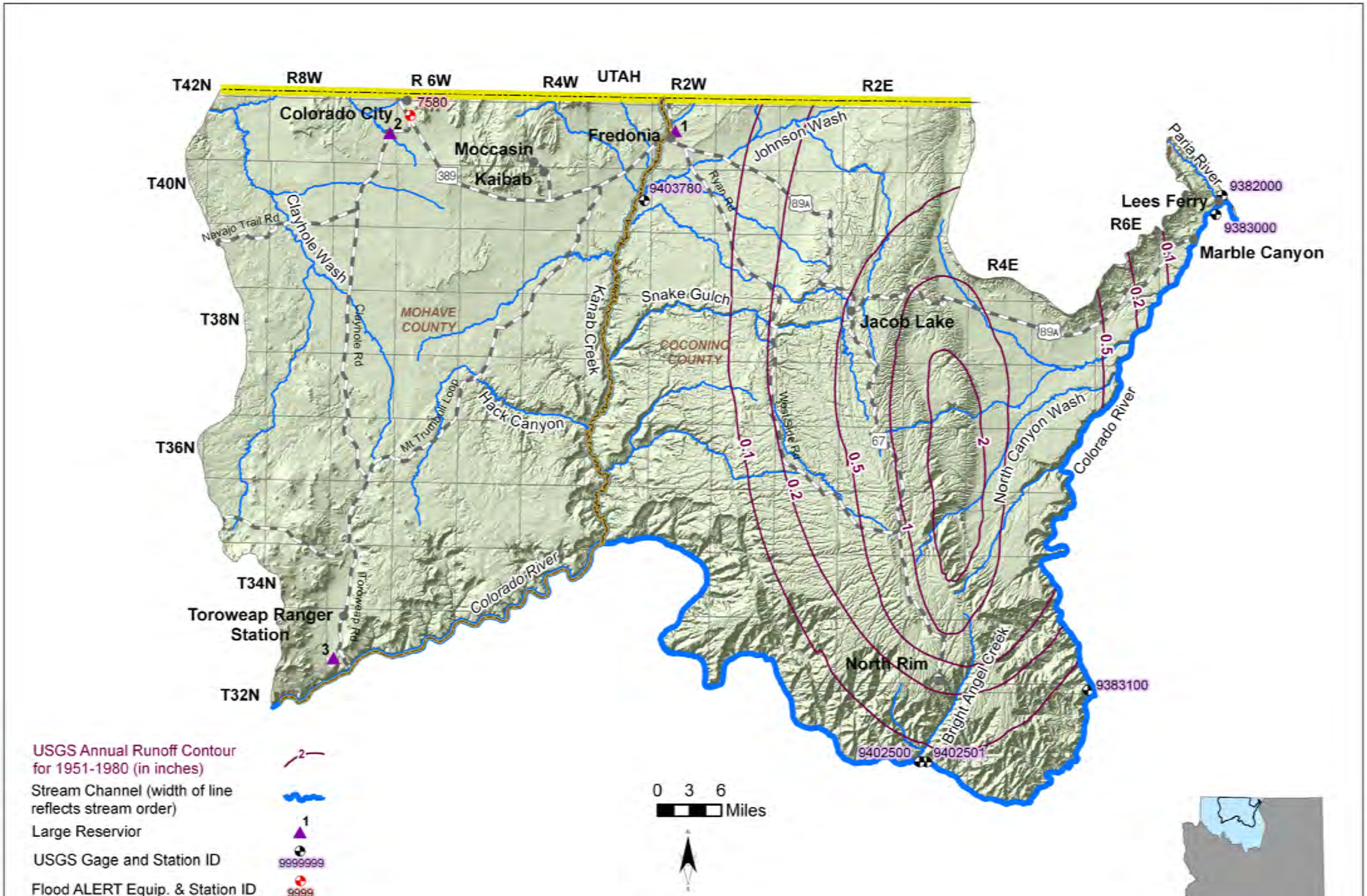


Figure 6.3-4
Kanab Plateau Basin
Surface Water Conditions

6.3.5 Perennial/Intermittent Streams and Major Springs in the Kanab Plateau Basin

Major and minor springs with discharge rates and date of measurement, and the total number of springs in the basin are shown in Table 6.3-5. The locations of major springs and perennial and intermittent streams are shown on Figure 6.3-6. A description of data sources and methods for intermittent and perennial reaches is found in Volume 1, Section 1.3.16. A description of spring data sources and methods is found in Volume 1, Section 1.3.14.

- The basin contains numerous perennial streams; most are located along and in the vicinity of the southern basin boundary. Significant perennial streams include the Colorado River, the Paria River and Kanab Creek.
- Intermittent streams are found south of Jacob Lake and in the vicinity of the Colorado River. Most of Kanab Creek is also intermittent in the basin.
- There are 39 major springs with a measured discharge of 10 gallons per minute (gpm) or greater at any time.
- Listed discharge rates may not be indicative of current conditions. Many of the measurements were taken during or prior to 1996.
- Most springs are located in the vicinity of the Colorado River. There is also a cluster of springs in the Moccasin/Kaibab area.
- Springs with measured discharge of 1 to 10 gpm are not mapped but coordinates are given in Table 6.3-5B. There are 23 minor springs in this basin.
- The total number of springs, regardless of discharge, identified by the USGS varies from 181 to 190, depending on the database reference.

Table 6.3-5 Springs in the Kanab Plateau Basin

A. Major Springs (10 gpm or greater):

Map Key	Name	Location		Discharge (in gpm)[1]	Date Discharge Measured
		Latitude	Longitude		
1	Tapeats (above Thunder)	362425	1122546	18,763	11/9/2003
2	Thunder at Tapeats	362346	1122728	9,741	11/9/2003
3	Angel	361317	1120040	7,810	10/14/92
4	Shinumo	361808	1121808	4,058	4/27/2002
5	Deer Creek	362322	1123027	3,542	5/31/2000
6	Roaring	361143	1120207	1,952	7/13/2003
7	Kanab Creek	362335	1123745	1,619	10/5/1993
8	Clear Creek	360454	1120208	772	4/24/2002
9	Dragon	361043	1121055	627	7/30/1969
10	Haunted	360935	1120636	430	8/15/1969
11	Abyss River	361721	1121528	403	7/13/1969
12	Fence Fault North	363139	1115044	300	3/26/2001
13	Stone Creek (below falls)	362050	1122708	265	3/1/2002
14	At Last	361716	1115745	260	7/29/1969
15	Crystal	361153	1121215	247	3/18/2004
16	Emmett[2]	361257	1120135	215	7/22/1969
17	Nankoweap Creek	361809	1115205	193	4/22/2002
18	Big	363608	1122054	185	7/2/2000
19	Ribbon[2]	361012	1120435	184	8/16/1969
20	Clear Water	364606	1123712	155	1/25/1997
21	Kwagunt Creek near Colorado R.	361542	1114948	137	10/14/1995
22	Vasey's Paradise	362957	1115126	119	3/14/2004
23	North Canyon (multiple)	362354	1120500	108	6/28/2000
24	Chuar Creek[2]	361000	1115147	100	10/12/1997
25	Long Res	365438	1124535	90	9/9/1976
26	Sand	365424	1124429	81	6/18/1997
27	Butte Fault-Upper	361658	1115318	76	3/27/2001
28	Phantom	360906	1120749	72	8/15/1969
29	Robber's Roost	361650	1120516	56[3]	7/7/1998
30	Noble[2]	361740	1121755	54	7/13/1969
31	Transcept[2]	361125	1120340	54	8/17/1969
32	Pipe	365149	1124422	35[3]	7/27/1976
33	Cottonwood	365829	1123601	25	11/15/1996
34	Mangum	363720	1122022	25	8/8/1976

Table 6.3-5 Springs in the Kanab Plateau Basin (cont'd)

Map Key	Name	Location		Discharge (in gpm)[1]	Date Discharge Measured
		Latitude	Longitude		
35	Two Mile Seep	365047	1123942	21	11/14/1996
36	Mocassin	365437	1124546	20	During or Prior to 1997
37	Soap Creek[2]	364645	1114613	18	8/4/1976
38	Tunnel	365147	1124420	11	8/8/2000
39	Kanabownits	361714	1121246	10	6/1/1976

B. Minor Springs (1 to 10 gpm):

Name	Location		Discharge (in gpm)[1]	Date Discharge Measured
	Latitude	Longitude		
South Big	361906	1121537	9	06/1975
Sprayfield	361302	1120405	8	06/1975
Warm	364141	1121842	6	7/3/2000
Unnamed	362044	1124015	5	4/4/2001
Castle	363509	1122027	4	7/2/2000
Sowats	363139	1122718	4	7/1/2000
Cliff Dweller	361221	1120340	3	07/1976
Unnamed[2,4]	361257	1120403	3	6/1/1976
Riggs	365655	1123729	2	11/15/1996
Little	362038	1130901	2	8/16/1950
Quaking Aspen	362243	1121654	2	6/29/2000
Milk Creek	361616	1120835	2	8/5/2000
Fern Glen[2]	361543	1125503	2	5/8/1976
Nixon	362408	1130846	1	6/20/2000
Sowats B	363127	1122718	1	7/1/2000
Timp	362316	1121743	1	8/8/2000
Coyote	365707	1120203	1	8/6/1976
Watts	362247	1121631	1	6/29/2000
Wolf	365853	1123809	1	11/15/1996
Saddle Horse	361345	1130317	1	8/9/1976
Unnamed	362047	1124329	1	5/7/1976
Yellowstone	364352	1125633	1	8/15/1951
Point	365516	1124322	1	11/15/1996

C. Total number of springs, regardless of discharge, identified by USGS (see ALRIS, 2005 and NHD, 2006): 181 to 190

Notes:
[1] Most recent measurement identified by ADWR
[2] Spring is not displayed on current USGS topo map
[3] Spring flow is highly variable. Earlier measurement is shown, most recent measurement < 10gpm
[4] Location approximated by ADWR

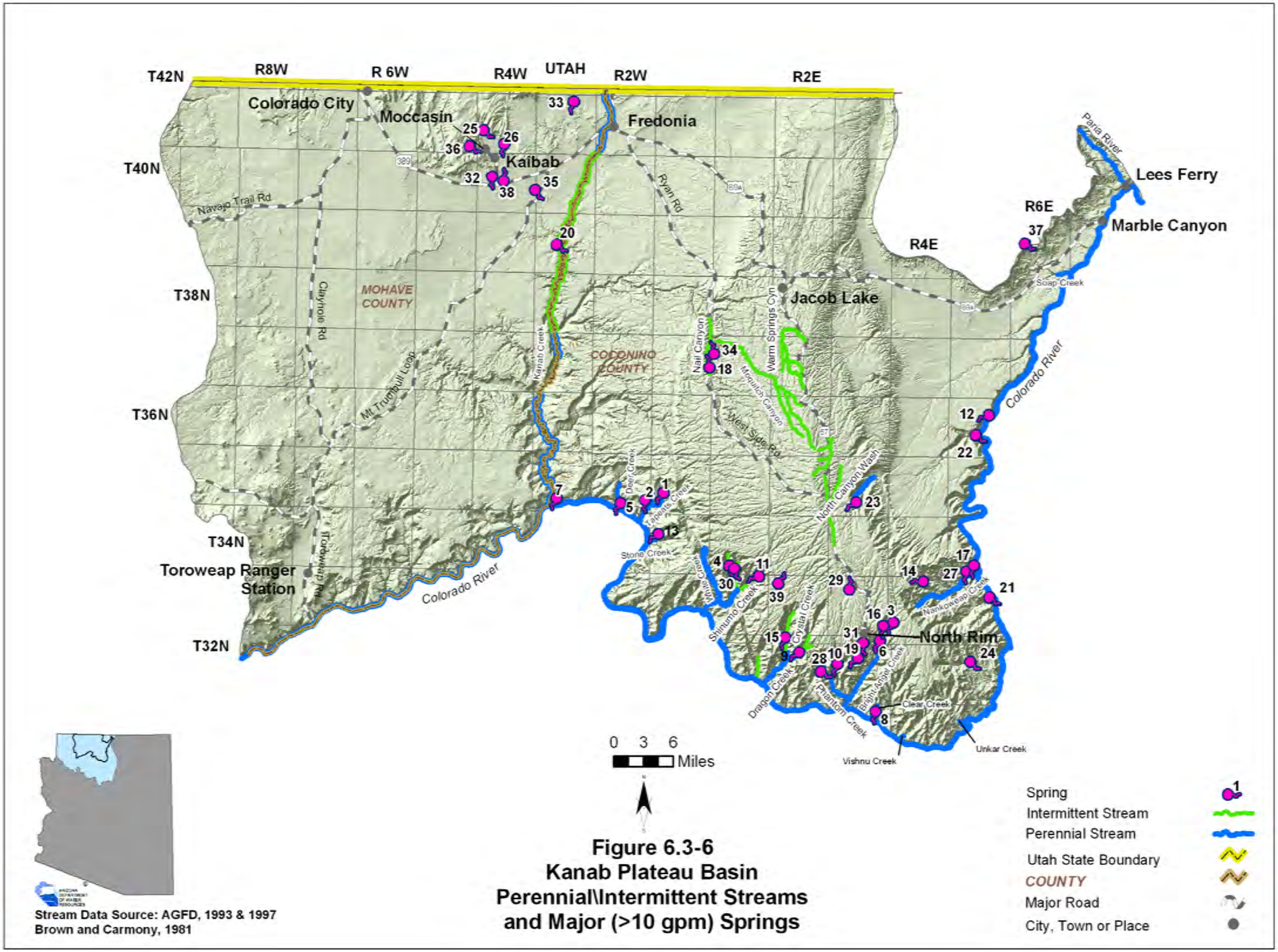


Figure 6.3-6
Kanab Plateau Basin
Perennial\Intermittent Streams
and Major (>10 gpm) Springs

6.3.6 Groundwater Conditions of the Kanab Plateau Basin

Major aquifers, well yields, number of index wells and date of last water-level sweep are shown in Table 6.3-6. Figure 6.3-7 shows water-level change between 1990-1991 and 2003-2004. Figure 6.3-8 contains hydrographs for selected wells shown on Figure 6.3-7. Figure 6.3-9 shows well yields in three yield categories. A description of aquifer data sources and methods is found in Volume 1, Section 1.3.2. A description of well data sources and methods, including water-level changes and well yields, is found in Volume 1, Section 1.3.19.

Major Aquifers

- Refer to Table 6.3-6 and Figure 6.3-7.
- Major aquifers in the basin include recent stream alluvium and sedimentary rock.
- Almost all of the basin geology consists of consolidated crystalline and sedimentary rock.
- Data on groundwater flow direction is not available for this basin.

Well Yields

- Refer to Table 6.3-6 and Figure 6.3-9.
- As shown on Figure 6.3-9, well yields in this basin range from less than 100 gallons per minute (gpm) to 1,000 gpm.
- One source of well yield information, based on 10 reported wells, indicates that the median well yield in this basin is 70 gpm.

Water Level

- Refer to Figure 6.3-7. Water levels are shown for wells measured in 2003-2004.
- The Department annually measures three index wells in this basin, two are shown on Figure 6.3-7 with hydrographs for these wells shown in Figure 6.3-8.
- For the two wells shown on Figure 6.3-7 depth to water was 87 feet at one well and 611 feet at the other. Water level change was minimal between 1990-1991 and 2003-2004.

Table 6.3-6 Groundwater Data for the Kanab Plateau Basin

Basin Area, in square miles:	4,247	
Major Aquifer(s):	**Name and/or Geologic Units**	
	Recent Stream Alluvium	
	Sedimentary Rock	
Well Yields, in gal/min:	Range 236-480 Median 358 (2 wells measured)	Measured by ADWR and/or USGS
	Range 3-500 Median 70 (10 wells reported)	Reported on registration forms for large (> 10-inch) diameter wells
	Range 30-200	ADWR (1990 and 1994)
	Range 0-500	USGS (1994)
Estimated Natural Recharge, in acre-feet/year:	N/A	
Estimated Water Currently in Storage, in acre-feet:	N/A	ADWR (1990 and 1994)
	N/A	Arizona Water Commission (1975)
Current Number of Index Wells:	3	
Date of Last Water-level Sweep:	1976 (62 wells measured)	

N/A = Not Available

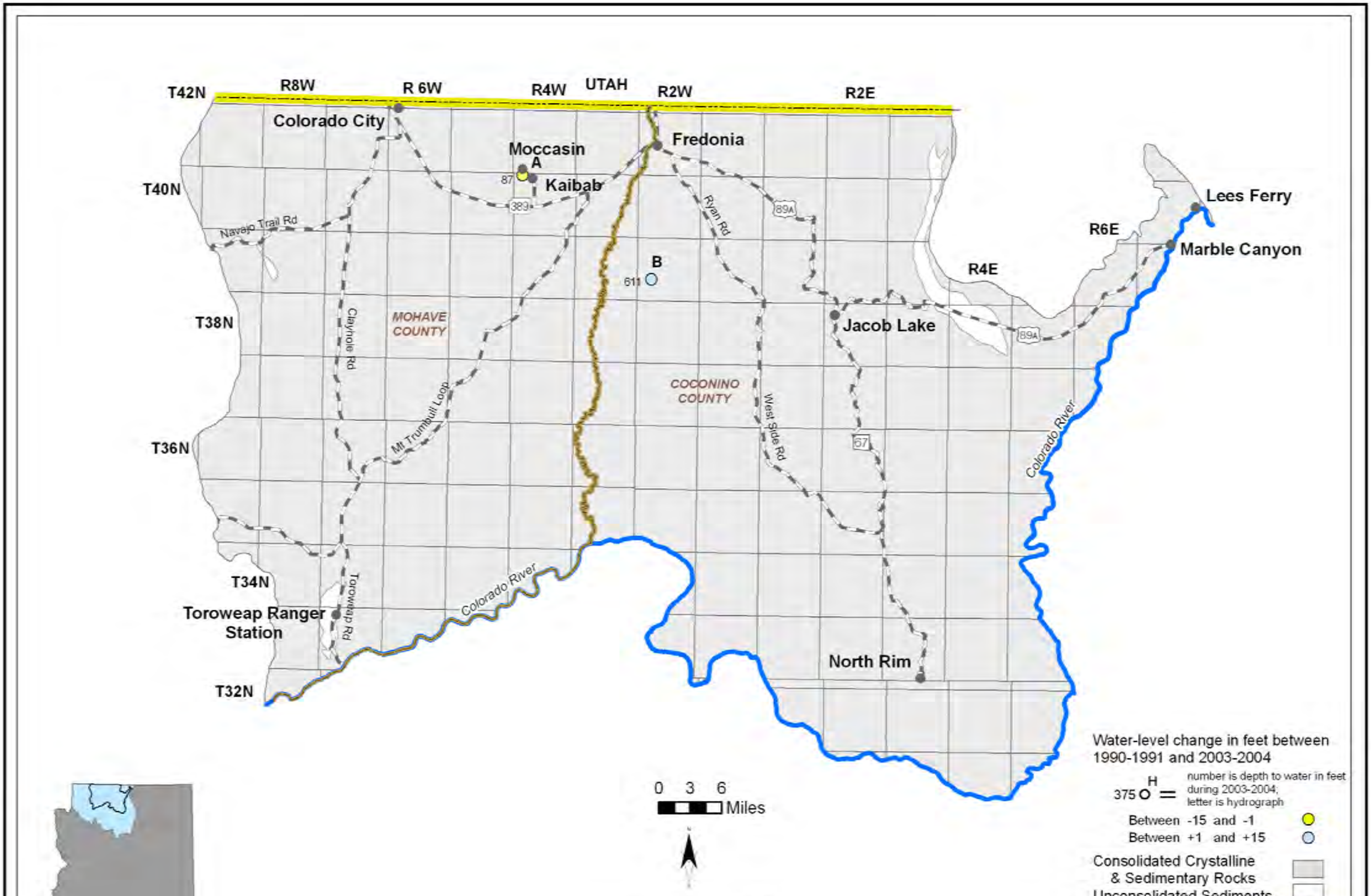
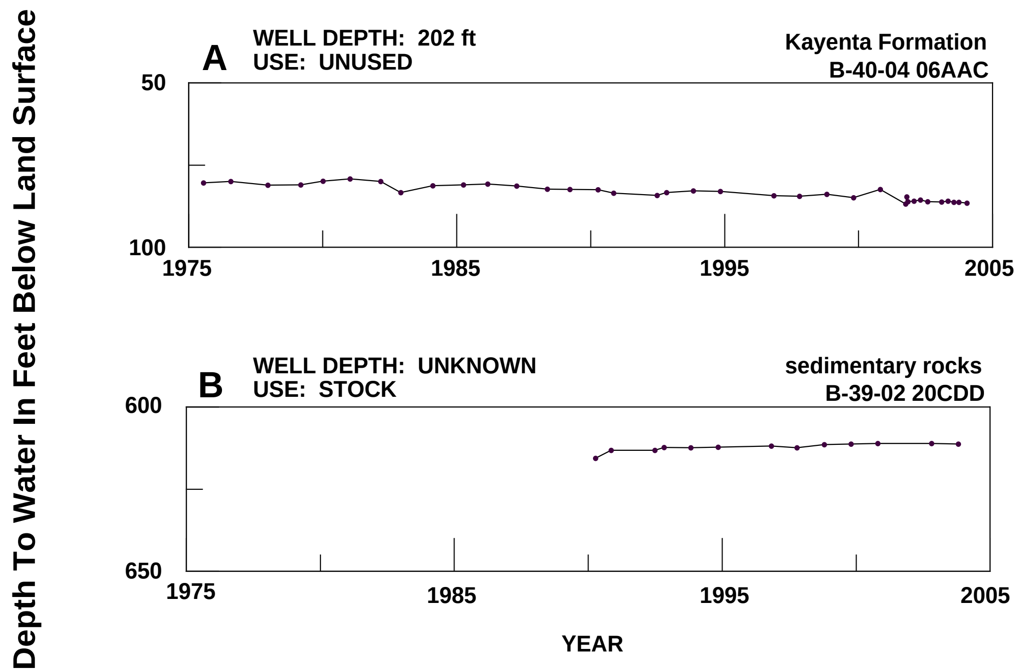


Figure 6.3-7
Kanab Plateau Basin
Groundwater Conditions

Figure 6.3-8
Kanab Plateau Basin
Hydrographs Showing Depth to Water in Selected Wells



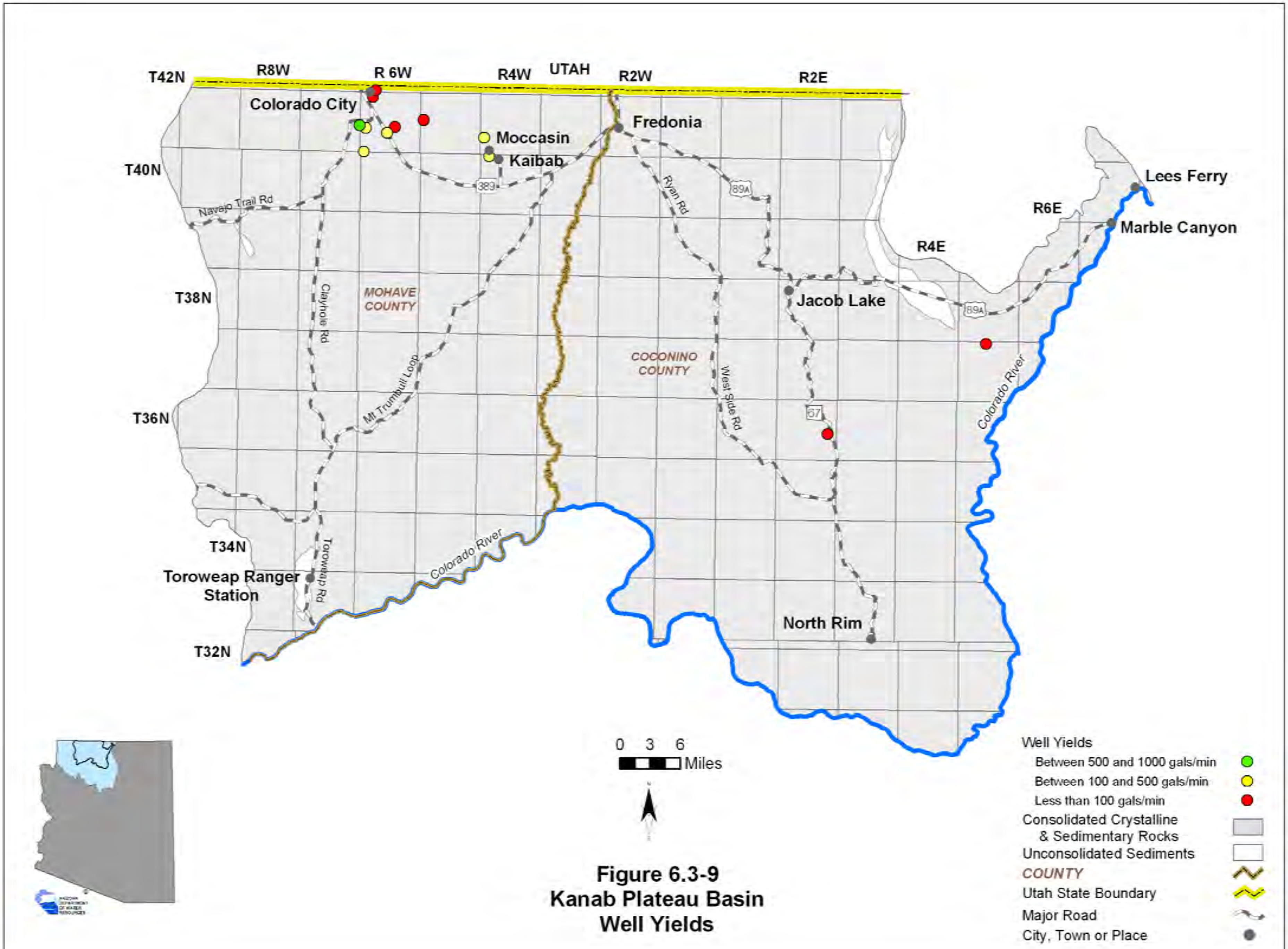


Figure 6.3-9
Kanab Plateau Basin
Well Yields

6.3.7 Water Quality of the Kanab Plateau Basin

Wells, springs and mine sites with parameter concentrations that have equaled or exceeded drinking water standard(s), including location and parameter(s) are shown in Table 6.3-7A. Impaired lakes and streams with site type, name, length of impaired reach, area of impaired lake, designated use standard and parameter(s) exceeded is shown in Table 6.3-7B. Figure 6.3-10 shows the location of water quality occurrences keyed to Table 6.3-7. A description of water quality data sources and methods is found in Volume 1, Section 1.3.18. Not all parameters were measured at all sites; selective sampling for particular constituents is common.

Wells, Springs and Mines

- Refer to Table 6.3-7A.
- Eight wells or springs have parameter concentrations that have equaled or exceeded drinking water standards.
- The parameter most frequently equaled or exceeded in the sites measured was total dissolved solids.
- Other parameters equaled or exceeded are lead and nitrates.

Lakes and Streams

- Refer to Table 6.3-7B.
- The water quality standard for suspended sediment concentration was exceeded in one 29-mile stream reach, the Paria River from the Utah border to the Colorado River. A portion of this impaired reach is located in the Paria Basin.
- This reach is not part of the ADEQ water quality improvement effort called the Total Maximum Daily Load (TMDL) Program at this time.

Effluent Dependent Reaches

- See Figure 6.3-9
- There is one effluent dependent reach in this basin, Transect Canyon. This reach receives effluent from the North Rim Wastewater Treatment Plant.

Table 6.3-7 Water Quality Exceedences in the Kanab Plateau Basin[1]

A. Wells, Springs and Mines

Map Key	Site Type	Site Location			Parameter(s) Concentration has Equaled or Exceeded Drinking Water Standard (DWS)[2]
		Township	Range	Section	
1	Well	37 North	5 East	4	TDS
2	Well	41 North	1 West	15	TDS
3	Well	41 North	4 West	31	Pb
4	Well	41 North	7 West	23	NO3
5	Spring	40 North	4 West	17	Pb
6	Well	40 North	7 West	4	TDS
7	Well	40 North	8 West	17	TDS
8	Well	39 North	4 West	24	TDS

B. Lakes and Streams

Map Key	Site Type	Site Name	Length of Impaired Stream Reach (in miles)	Area of Impaired Lake (in acres)	Designated Use Standard[3]	Parameter(s) Exceeding Use Standard[2]
a	Stream	Paria River (Utah border to Colorado River)	29[4]	NA	A&W	SSC

Notes:

NA = Not Applicable
[1] Water quality samples collected between 1976 and 2001.
[2] Pb = Lead
NO3 = Nitrate
TDS = Total Dissolved Solids
SSC = Suspended Sediment Concentration
[3] A&W = Aquatic and Wildlife
[4] Total length of the impaired reach. A portion of this reach is in the Paria Basin.

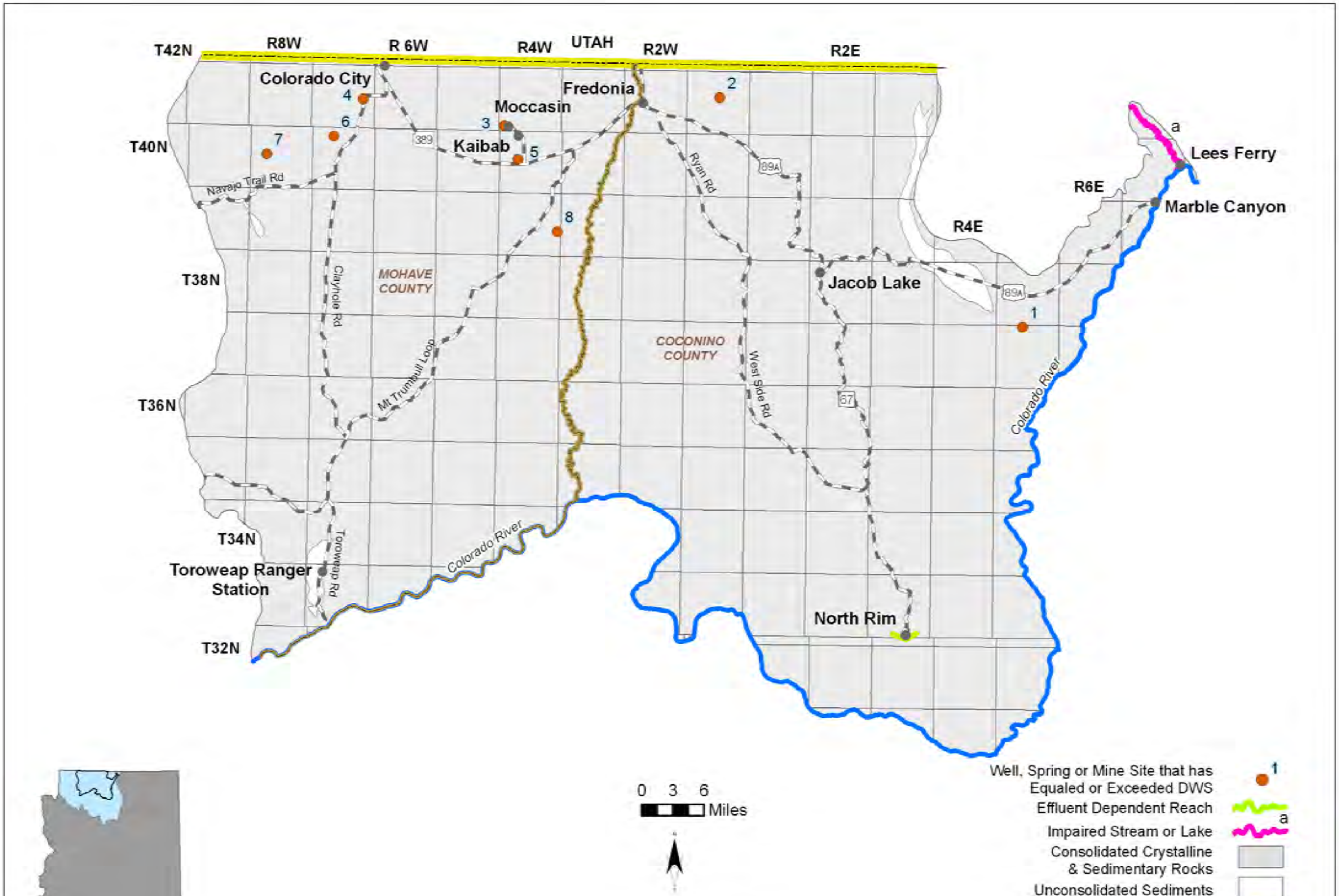


Figure 6.3-10
Kanab Plateau Basin
Water Quality Conditions

6.3.8 Cultural Water Demands in the Kanab Plateau Basin

Cultural water demand data including population, number of wells and the average well pumpage and surface water diversions by the municipal, industrial and agricultural sectors are shown in Table 6.3-8. Effluent generation including facility ownership, location, population served and not served, volume treated, disposal method and treatment level is shown in Table 6.3-9. Figure 6.3-11 shows the location of demand centers. A description of cultural water demand data sources and methods is found in Volume 1, Section 1.3.5. More detailed information on cultural water demands is found in Section 6.0.7.

Cultural Water Demands

- Refer to Table 6.3-8 and Figure 6.3-11.
- Population in this basin increased from 2,815 in 1980 to 5,930 in 2000 and is projected to reach 12,329 by 2050.
- Groundwater demand has been approximately 2,000 acre-feet per year on average from 1976-2003.
- Groundwater is used for both municipal and agricultural demand. Municipal and agricultural demand centers are located in the vicinity of Fredonia, Colorado City, Moccasin and Kaibab.
- All surface water use is for municipal demand. Data on surface water use prior to 1991 is not available. The table includes approximately 500 acre-feet of surface water that is diverted from Roaring Spring in this basin for use at the Grand Canyon South Rim in the Coconino Plateau Basin.
- As of 2007 there were no active mines in the basin. It is likely, however, that three uranium mines, Arizona One, Canyon and Pinenut will be operated in the future.
- As of 2003 there were 247 registered wells with a pumping capacity of less than or equal to 35 gallons per minute and 65 wells with a pumping capacity of more than 35 gallons per minute.

Effluent Generation

- Refer to Table 6.3-9.
- There are five wastewater treatment facilities in this basin.
- Information on population served was available for two facilities and information on effluent generation was available for four facilities. These facilities serve over 2,900 people and generate over 400 acre-feet of effluent per year. In the past Colorado City operated a wastewater treatment facility that served over 5,000 people and generated 403 acre-feet per year. The plant closed in 2002 and Colorado City now sends sewage to Hildale, Utah for treatment.
- Of the five facilities with information on the effluent disposal method: one discharges to evaporation ponds; two discharge for irrigation; and one discharges to unlined impoundments that recharge the aquifer.

Table 6.3-8 Cultural Water Demands in the Kanab Plateau Basin[1]

Year	Recent (Census) and Projected (DES) Population	Number of Registered Water Supply Wells Drilled		Average Annual Demand (in acre-feet)						
				Well Pumpage			Surface-Water Diversions			Data Source
		Q ≤ 35 gpm	Q > 35 gpm	Municipal	Industrial	Irrigation	Municipal[2]	Industrial	Irrigation	
1971		171[3]	50[3]	<500			NR[4]			ADWR (1994)
1972										
1973										
1974										
1975										
1976				2,000			NR			
1977										
1978										
1979										
1980	2,815									
1981	2,985	6	5	2,000			NR			
1982	3,155									
1983	3,324									
1984	3,494									
1985	3,664									
1986	3,834	18	6	2,000			NR			
1987	4,004									
1988	4,174									
1989	4,343									
1990	4,513									
1991	4,655	10	1	800	NR	1,500	900	NR	<1,000	USGS (2005) ADWR (2005)
1992	4,797									
1993	4,938									
1994	5,080									
1995	5,222									
1996	5,364	23	1	1,000	NR	1,500	900	NR	<1,000	
1997	5,505									
1998	5,647									
1999	5,789									
2000	5,930									
2001	6,156	5	2	1,000	NR	<1,000	900	NR	<1,000	
2002	6,382									
2003	6,608									
2010	8,190									
2020	9,476									
2030	10,570									
2040	11,463									
2050	12,329									
ADDITIONAL WELLS:[5]		**14**								
WELL TOTALS:		**247**	**65**							

[1] Does not include evaporation losses from stockponds and reservoirs.
[2] Surface water diverted in the Kanab Plateau Basin is delivered to the Coconino Plateau Basin for use at the Grand Canyon South Rim.
[3] Includes all wells through 1980.
[4] Surface water diversions for irrigation occurred in the Fredonia area prior to 1990 however data on the volume of surface water diversions is not available.
[5] Other water-supply wells are listed in the ADWR Well Registry for this basin, but they do not have completion dates. These wells are summed here.
NR - Not reported

Table 6.3-9 Effluent Generation in the Kanab Plateau Basin

Facility Name	Ownership	City/Location Served	Population Served	Volume Treated /Generated (acre-feet)	Disposal Method								Current Treatment Level	Population Not Served	Year of Record
					Water-course	Evaporation Pond	Irrigation	Wildlife Area	Golf Course	Municipal Reuse	Discharged to Another Facility	Infiltration Basins			
Fredonia WWTF	Fredonia	Fredonia	1,395	157		X							Secondary w/ Nutrient Removal	1,025	1998
Jacob Lake	Private	Jacob Lake	NA												
Kaibab Lagoons	NA	NA	1,500	168								X	Secondary	NA	2000
North Rim-Grand Cayon WWTP	National Park Service	Park	NA	112	Trancept Canyon		X						NA		2002
Phantom Ranch	National Park Service	Park	NA	10			X						NA		2002
Total			2,895	447											

NA: Data not currently available to ADWR
WWTF: Waste Water Treatment Facility
WWTP: Waste Water Treatment Plant

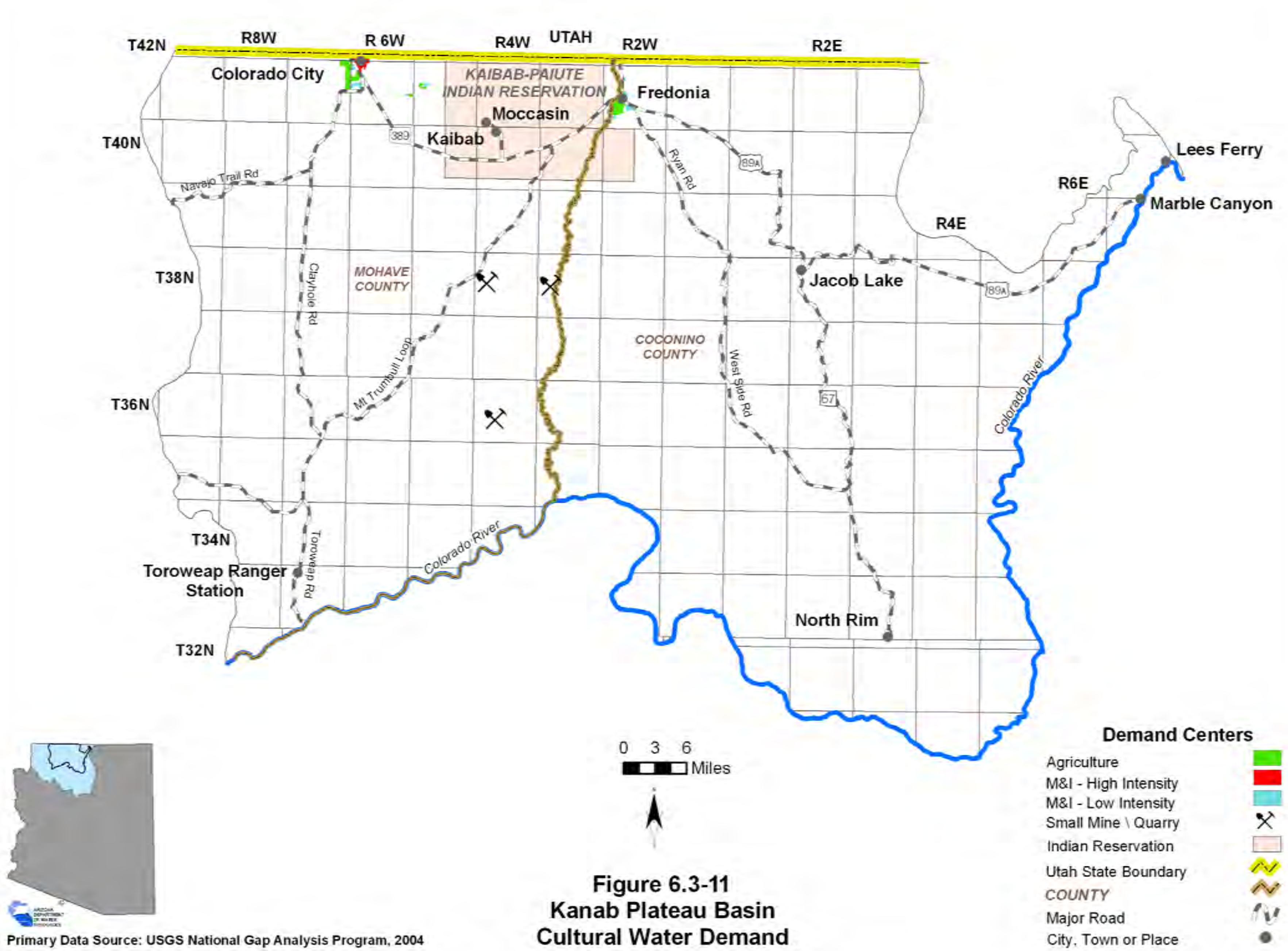


Figure 6.3-11
Kanab Plateau Basin
Cultural Water Demand

6.3.9 Water Adequacy Determinations in the Kanab Plateau Basin

Water adequacy determination information including the subdivision name, location, number of lots, adequacy determination, reason for the inadequacy determination, date of determination and subdivision water provider are shown in Table 6.3-10. Figure 6.3-12 shows the locations of subdivisions keyed to the Table. A description of the Water Adequacy Program is found in Volume 1, Appendix A. Adequacy determination data sources and methods are found in Volume 1, Sections 1.3.1.

Water Adequacy Reports

- See Table 6.3-10
- Six of the nine water adequacy determinations made in this basin through May, 2005 were determinations of inadequacy.
- Most of the inadequacy determinations were because the applicant chose not to submit the necessary information, and/or the available hydrologic data was insufficient to make a determination.
- The number of lots receiving a water adequacy determination, by county, are:

County	Number of Subdivision Lots	Number of Lots Determined to be Adequate	Percent Adequate
Coconino County	229	70	31%
Mohave County	131	131	100%

Table 6.3-10. Adequacy Determinations in the Kanab Plateau Basin[1]

Map Key	Subdivision Name	County	Location			No. of Lots	ADWR File No.[2]	ADWR Adequacy Determination	Reason(s) for Inadequacy Determination[3]	Date of Determination	Water Provider at Time of Application
			Township	Range	Section						
1	Centennial Park Unit 1	Mohave	41 North	6 West	18	66	22-300320	Adequate		08/16/99	Centennial Park Utilities
2	Cliff Dweller's Homelands	Coconino	39 North	6 East	28, 33	6		Inadequate	A1	07/11/88	Dry Lot Subdivision
3	Cowboy Butte Estates	Coconino	41 North	2 West	5, 8	13		Inadequate	A1	06/23/88	Town of Fredonia
4	Gateway Mobile Home Park	Mohave	41 North	2 West	17, 21	65		Adequate		03/17/78	Town of Fredonia
5	Gateway Mobile Park	Coconino	41 North	2 West	17	70		Inadequate	A1, B	4/24/1986	Town of Fredonia
6	Heaton Subdivision	Coconino	41 North	2 West	16	28		Inadequate	A1	03/18/85	Town of Fredonia
7	Lewis Estates Subdivision	Coconino	41 North	2 West	16, 21	16	22-400613	Inadequate	C	10/29/01	Town of Fredonia
8	Roadrunner Estates	Coconino	41 North	2 West	20	26		Inadequate	A1	03/26/84	Town of Fredonia
9	Shiprock Estates	Coconino	41 North	2 West	17, 21	70		Adequate		03/17/78	Town of Fredonia

Notes:

[1] Each determination of the adequacy of water supplies available to a subdivision is based on the information available to ADWR and the standards of review and policies in effect at the time the determination was made. In some cases, ADWR might make a different determination if a similar application were submitted today, based on the hydrologic data and other information currently available, as well as current rules and policies.

[2] Prior to February 1995, ADWR did not assign file numbers to applications for adequacy determination.

[3] A. Physical/Continuous
1) Insufficient Data (applicant chose not to submit necessary information, and/or available hydrologic data insufficient to make determination)
2) Insufficient Supply (existing water supply unreliable or physically unavailable;for groundwater, depth-to-water exceeds criteria)
3) Insufficient Infrastructure (distribution system is insufficient to meet demands or applicant proposed water hauling)

B. Legal (applicant failed to demonstrate a legal right to use the water or failed to demonstrate the provider's legal authority to serve the subdivision)
C. Water Quality
D. Unable to locate records

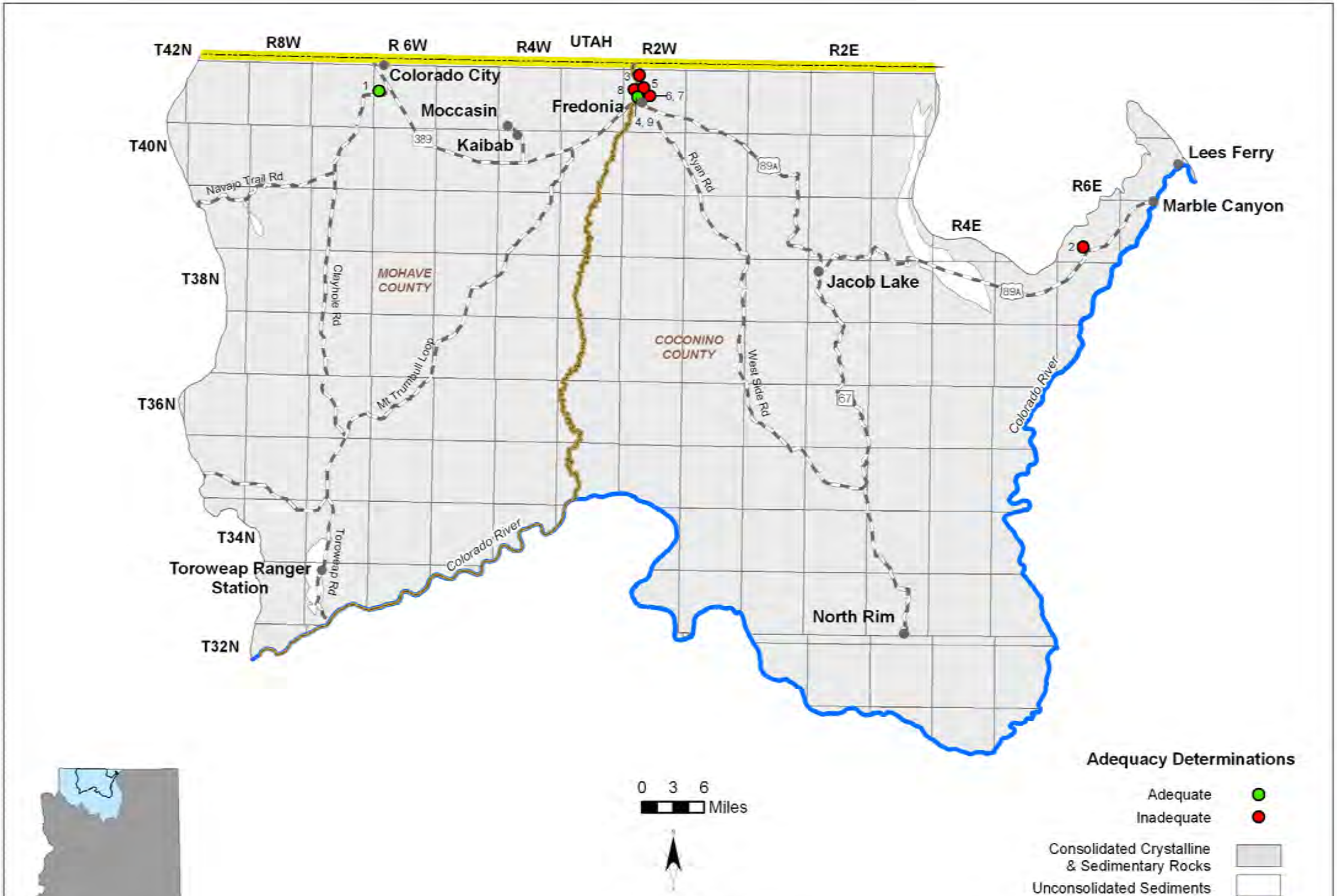


Figure 6.3-12
Kanab Plateau Basin
Adequacy Determinations

Kanab Plateau Basin
References and Supplemental Reading

References

A

Arizona Corporation Commission (ACC), 2005, Annual reports, Private Sewer companies, 1990 to 2005: ACC Utilities Division.

_____, 2005, Annual reports, Small water providers, 1990 to 2005: ACC Utilities Division.

Arizona Crop and Livestock Reporting Service, 1973, 1972 Arizona Agricultural Statistics: Bulletin S-8.

Arizona Department of Economic Security (DES), 2005, Workforce Informer: Data file, accessed August 2005, http://www.workforce.az.gov.*

Arizona Department of Environmental Quality, 2005, Active dairy farms & feedlots: Data file, received October 2005.

Arizona Department of Environmental Quality, 2005, ADEQSWI: Data file, received September 2005.

_____, 2005, ADEQWATP: Data file, received May 2005.

_____, 2005, ADEQWWTP: Data file, received August 2005.*

_____, 2005, Azurite: Data file, received September 2005.

_____, 2005, Effluent dependent waters: GIS cover, received December 2005.*

_____, 2005, Impaired lakes and reaches: GIS cover, received January 2006.

_____, 2005, Surface water sources used by water providers: Data file, received June 2005.*

_____, 2005, WWTP and permit files: Miscellaneous working files, received July 2005.

_____, 2004, Water providers with arsenic concentrations in wells over 10ppb: Data file, received August 2004.

_____, 2004, Water quality exceedences by watershed: Data file, received June 2004.

_____, 2004, Water quality exceedences for drinking water providers in Arizona: Data file, received September 2004.

Arizona Department of Mines and Mineral Resources (ADMMR), 2005, Active mines in Arizona: Database, accessed at http:// www.admmr.state.az.us.

Arizona Department of Water Resources (ADWR), 2006, Assured and adequate water supply applications: Project files, ADWR Hydrology Division.*

_____, 2005, Agricultural Surface Water Use Estimates: Unpublished analysis, ADWR Office of Resource Assessment Planning.

_____, 2005, Automated recorder sites: Data files, ADWR Basic Data Unit.*

_____, 2005, 2004 rural water provider questionnaire: Data files, ADWR Office of Resource Assessment Planning.*

_____, 2005, Assured and adequate water supply determinations: Database, ADWR Office of Assured and Adequate Water Supply.*

_____, 2005, Flood warning gages: Database, ADWR Office of Water Engineering.*

______, 2005, Inspected dams: Database, ADWR Office of Dam Safety.*

______, 2005, Non-jurisdictional dams: Database, ADWR Office of Dam Safety.

______, 2005, Groundwater Site Inventory (GWSI): Database, ADWR Hydrology Division.

_______, 2005, Registry of surface water rights: ADWR Office of Water Management.
_______, 2005, Water Protection Fund: Database, ADWR Office of Drought, Conservation and Riparian Planning.
______, 2005, Water use by golf courses in rural Arizona: Unpublished analysis, ADWR Office of Regional Strategic Planning.
______, 2005, Wells55: Database.*
______, 2002, Groundwater quality exceedences in rural Arizona from 1975 to 2001: Data file, ADWR Office of Regional Strategic Planning.*
______, 1994, Arizona Water Resources Assessment, Vol. I, Inventory and Analysis.*
______, 1994, Arizona Water Resources Assessment, Vol. II, Hydrologic Summary.*
______, 1990, Draft outline of basin profiles for the state water assessment: ADWR Statewide Planning Division, Memorandum to L. Linser, D.W., January, 16, 1990.*
Arizona Game and Fish Department (AGF), 2005, Arizona Waterways: Data file, received April 2005.
______, 1997 & 1993, Statewide riparian inventory and mapping project: GIS cover.
______, 1982, Arizona Lakes Classification Study.
Arizona Land Resource Information System (ALRIS), 2005, Springs: GIS cover, accessed January 2006 at http://www.land.state.az.us/alris/index.html.*
______, 2005, Streams: GIS cover, accessed 2005 at http://www.land.state.az. us/alris/index. html.*
______, 2005, Water features: GIS cover, accessed July 2005 at http://www.land.state.az. us/alris/ index.html.*
_______, 2004, Land ownership: GIS cover, accessed in 2004 at http://www.land. state.az.us/alris/index.html.*
Arizona Meteorological Network (AZMET), 2005, Arizona climate stations: Pan evaporation data, accessed December 2005 at http://www.ag.arizona.edu/ azmet/locate.html.
Arizona Water Commission, 1975, Summary, Phase I, Arizona State Water Plan, Inventory of resource and uses.

D

Diroll, M., and Marsh, D., 2006, Status of water quality in Arizona-2004 integrated 305(b) assessment and 303(d) listing report: ADEQ report.

E

Environmental Protection Agency (EPA), 2005, Surf Your Watershed: Facility reports, accessed April 2005 at http://oaspub.epa.gov/enviro/ef_home2.water.*
______, 2005, 2000 and 1996, Clean Watershed Needs Survey: datasets, accessed March 2005 at http://www.epa.gov/owm/mtb/cwns/index.htm.*

F

Fisk, G.G., Duet, D.W., Evans, C.E., Angernoth, N.K., and Longsworth, S.A., 2004, Water Resources Data, Arizona Water Year 2003: USGS Water-Data Report AZ-03-1.*

G

Grand Canyon Wildlands Council, 2002, Arizona Strip Springs, Seeps and Natural

Ponds: Inventory, Assessment and Development of Recovery Priorities: AZ Water Protection Fund 99-074.*

K

Konieczki, A.D. and Wilson, R.P., 1992, Annual summary of ground-water conditions in Arizona, spring 1986 to spring 1987: USGS Open File Report 92-54.*

M

McCormack, H.F., Fisk, G.G., Duet, N.R., Evans, D.W., Roberts, W.P., and Castillo, N.K., 2002, Water resources data Arizona, water year 2002: USGS Water Data Report AZ-02-1.*

N

National Park Service, 2004, Grand Canyon springs: Electronic data file, sent November 2004*

Natural Resources Conservation Service (NRCS), 2005, SNOTEL (Snowpack Telemetry) stations: Data file, accessed December 2005 at http://www3.wcc.nrcs.usda.gov /nwcc/sntlsites.jsp?state=AZ.*

______, 2005, Snow Course stations: Data file, accessed December 2005 at http://www.wcc.nrcs.usda.gov/nwcc/snow-course-sites.jsp?state=AZ*

O

Oregon State University, Spatial Climate Analysis Service (SCAS), 2006, Average annual precipitation in Arizona for 1961-1990: PRISM GIS cover, accessed in 2006 at www.ocs.orst.edu/prism.*

P

Pope, G.L., Rigas, P.D., and Smith, C.F., 1998, Statistical summaries of streamflow data and characteristics of drainage basins for selected streamflow-gaging stations in Arizona through water year 1996: USGS Water Resources Investigations Report 98-4225.*

Price, D., and Arnow, T., 1974, Summary appraisals of the nation's groundwater resources, upper Colorado region: USGS Professional Paper 813-C.*

R

Reber, S. J., 1997, Hydrogeological Report, Centennial Park, Arizona. Prepared for Arizona Department of Water Resources.*

T

Tadayon, S., 2004, Water withdrawals for irrigation, municipal, mining, thermoelectric-power, and drainage uses in Arizona outside of the active management areas, 1991-2000: USGS Scientific Investigations Report 2004-5293, 27 pp.*

Truini, M.,1999, Geohydrology of Pipe Spring National Monument Arizona: USGS Open File Report 98-4263.*

U

US Army Corps of Engineers, 2004 and 2005, National Inventory of Dams: Arizona Dataset, accessed November 2004 to April 2005 at http://crunch.tec.army.mil/nid/

webpages/nid.cfm*
US Geological Survey (USGS), 2006, Average annual runoff in the United States, 1951-1980: Data file, accessed March 2006 at http://aa179.cr.usgs.gov/metadata /wrdmeta/runoff.htm.*
_____, 2006, Springs and spring discharges: Dataset, received November 2004 and January 2006 from USGS office in Tucson, AZ.*
_____, 2006, National Hydrography Dataset: Arizona dataset, accessed at http://nhd.usgs.gov/.*
_____, 2005, National Water Information System (NWIS): Arizona dataset, accessed December 2005 at http://waterdata.usgs.gov/nwis.
_____, 2004, Southwest Regional Gap analysis study- land cover descriptions: Electronic file, accessed January 2005 at http://earth.gis.usu.edu/swgap.*
_____, 1981, Geographic digital data for 1:500,000 scale maps: USGS National Mapping Program Data Users Guide.*

V

Valencia, R.A., Wennerlund, J.A., Winstead, R.A., Woods, S., Riley, L., Swanson, E., and Olson, S., 1993, Arizona riparian inventory and mapping project: Arizona Game and Fish Department.*

W

Wahl, C.R., Boe, S.R., Wennerlund, R.A., Winstead, R.A., Allison, L.J., Kubly, D.M., 1997, Remote sensing mapping of Arizona intermittent stream riparian areas: Arizona Game and Fish Technical Report 112.
Water Infrastructure Finance Authority of Arizona (WIFA), 2005, Clean Watershed Needs Survey-2004: Unpublished data sheets, received July 2005.
Wenrich, K.J., Boundt, S.Q., and others, 1994, Hydrochemical survey for mineralized breccia pipes- data from springs, wells and streams on the Hualapai Indian Reservation, Northwestern Arizona: USGS Open File Report 93-619.*
Western Regional Climate Center (WRCC), 2005, Pan evaporation stations: Data file accessed December 2005 at http://www4.ncdc.noaa.gov/cgi-win/wwcgi.dll?wwDI~GetCity~USA.
_____, 2005, Precipitation and temperature stations: Data file, accessed December 2005 at http://www4.ncdc.noaa.gov/cgi-win/wwcgi.dll?wwDI~GetCity~USA.*
Wilson, R.P., 1992, Summary of groundwater conditions in Arizona 1985 to 1986: USGS Water Resources Investigation Report, 90-4179.*

*All references marked with an asterisk contain information that was directly used in the basin summaries, tables or maps.

Supplemental Reading

Andersen, Mark, 2005, Assessment of water availability in the Lower Colorado River basin: in Conservation and Innovation in Water Management: Proceedings of the 18th annual Arizona Hydrological Society Symposium, Flagstaff, Arizona, September, 2005.

Bennett, J.B., 1997, A Biogeochemical characterization of reattachment bars of the Colorado River, Grand Canyon National Park, Arizona: Northern Arizona University, M.S. thesis, 148 pp.

Bennett, J. B. and Parnell, R. A., Jr., 1995, Nutrient cycling in the Colorado, Grand Canyon National Park, AZ, USA: 3rd Biennial Conference on the Colorado Plateau, Flagstaff, AZ.

Bureau of Reclamation, 2002, Grand Canyon National Park water supply appraisal study, Coconino, Mohave and Yavapai Counties, Arizona: Grand Canyon National Park report.

_____, 2006, North Central Arizona Water Supply Study: Report.

Carpenter, M., Carruth, R., Fink, J, Boling, J., and Cluer, B., 1995, Hydrogeology and deformation of sandbars in response to fluctuations in flow of the Colorado River in the Grand Canyon, USGS Water Resources Investigations Report 95-4010.

Enzel, Y., Ely, L.L., House, P.K., Baker, V.R., and Webb, R.H., 1993, Paleoflood evidence for a natural upper bound to flood magnitudes in the Colorado River Basin: Water Resources Research, vol. 29, no. 7, p. 2287-2297.

Flynn, M., Hornewer, N., 2003, Variations in sand storage measured at monumented cross sections in the Colorado River between Glen Canyon and Lava Falls rapid, Northern Arizona, 1992-1999:USGS Water Resources Investigations Report 03-4104, 39 p.

Freilich, Leitner & Carlisle, 2005, Mohave County General Plan: Water Resources Element.

Garrett, W.B., Van De Vanter, E.K., and Graf, J.B., 1993, Stream flow and sediment-transport data, Colorado River and three tributaries in the Grand Canyon, Arizona, 1983 and 1985-1986: USGS Open–File Report 93-174, 624 pp.

Gauger, R.W., 1997, River-stage data Colorado River, Glen Canyon Dam to upper Lake Mead, Arizona, 1990-1994: USGS Open–File Report 96-626, 20 pp.

Gilbert, B.A., 1997, Hydrogeologic parameters necessary to conserve backwater habitats of the Colorado River, Grand Canyon, Arizona: Geological Society of America, Abstracts with Programs, vol. 29, p. 177.

Hart, R.J., 1999, Water Quality of the Colorado River monitored by the USGS National Stream Quality Accounting Network: in Water Issues and Partnerships for Rural Arizona: Proceedings of the 12 th annual symposium of the Arizona Hydrological Society, September 1999, Hon Dah, Arizona.

Hazel, J. Jr., Kaplinski, M.A., Parnell, R.A. Jr., Manone, M., and A. Dale., 1999. Effects of the 1996 beach/habitat-building flow on Colorado River sand bars and sediment storage along the Colorado River Corridor: in The Controlled Flood in Grand Canyon, Webb, R.H., Schmidt, J. S., Marzolf, G. R., and Valdez, R. A. (eds): AGU Geophysical Monograph 110, American Geophysical Union, Washington, DC.

Hereford, R., Webb, G., and Graham, S., 2002, Precipitation history of the Colorado Plateau region, 1990 – 2000: USGS Fact sheet 119-02.

Inglis, R., 1997, Monitoring and analysis of spring flows at Pipe Springs NM, Arizona: NPS Technical Report NPS/NRWRD/NRTR-97125, 35 pp.

Inglis, R., 1997, Water resource data of the Pipe Springs National Monument area, Arizona: US Park Service Technical Report NPS/NRWRD/NRTR-90/02.

Kaplinski, M.A., Hazel, J. Jr., Parnell, R.A. Jr., Manone, M., Dale, A. and Topping, D., 1998, Sediment storage changes following short-duration high magnitude flow releases from Glen Canyon Dam, Grand Canyon National Park: Geological Society of America, Abstracts with Programs, vol. 30, p 12.

Kessler, J.A., 2002, Grand Canyon Springs and the Redwall - Muav Aquifer: Comparison of geologic framework and groundwater flow models: Northern Arizona University, M.S. thesis, 122 p.

Kobor, J.S., Springer, A.E., 2003, Predicting riparian vegetation response to groundwater withdrawals; an interdisciplinary modeling approach to a regional spring system, Grand Canyon, AZ: Geological Society of America, Abstracts with Programs, vol. 35, 6, p. 374.

Levings, G.W., Farrar, C.D., 1979, Map showing ground-water conditions in the Kanab area, Coconino and Mohave counties, Arizona: USGS Water Resources Investigations Report 79-1070.

Levings, G.W., Farrar, C.D., 1978, Map showing ground-water conditions in the House Rock area, Coconino County, Arizona: USGS Water Resources Investigations Report 78-15

Miller, J.L., 2004, The relationship of seasonal rainfall and recharge with in Grand Canyon’s north rim Redwall-Muav aquifer using d^{18}O and H: in The Value of Water; Proceedings from the 17th annual Arizona Hydrological Society symposium, September 2004, Tucson Arizona.

National Park Service, 1998, Hydrologic investigation and conservation planning, Pipe Springs, Arizona: Arizona Water Protection Fund Project 96-0004.

National Park Service, 1999, Baseline water quality data, inventory, and analysis, Pipe Springs National Monument: US Park Service Report NPS/NRWD/NRTR-99/220.

Parnell, R.A. Jr., Springer, A., Stevens, L., Bennett, J., Hoffnagle, T., Melis, T., and Staniski-Martin, D., 1997, Flood-induced backwater rejuvenation along the Colorado River Corridor in Grand Canyon, AZ.; in Patten, D. and Garrett, L. (eds.), Symposium on the Glen Canyon Dam Beach/Habitat-Building Flow: U.S. Bureau of Reclamation/ GCMRC, Flagstaff, AZ., p. 41-51.

Parnell, R.A. Jr., Springer, A., Bennett, J., Stevens, L., 1997, Effects of the 1996 Glen Canyon Dam controlled flood on nutrient spiraling along the Colorado River Corridor in Grand Canyon, AZ., in Patten, D. and Garrett, L. (eds.), Symposium on the Glen Canyon Dam Beach/Habitat-Building Flow. U.S. Bureau of Reclamation/GCMRC, Flagstaff, AZ., p. 52-56.

Parnell, R.A., Jr., Stevens, L.W., Bennett, J.B., Hazel, J.E., Jr., Kaplinski, M., Manone, M.F., and Dale, A.R., 1997, Impacts of controlled flooding on physical and chemical characteristics of riparian ecosystems along the Colorado River, Grand Canyon, Arizona: Geological Society of America Abstracts with Programs, v. 29, p. 177.

Petroutson, W.D., 1997, Interpretive simulations of advective flowpaths across a reattachment bar during different Colorado River flow alternatives: Northern Arizona University, M.S. thesis, 159 pp.

Petroutson, W. D., Springer, A.E., 1995, Characterizing stage-dependent measurements of hydraulic conductivity of reattachment bars in the Colorado River: Geological Society of America, Abstracts with Programs, vol. 27, p. 34.

Rocky Mountain Institute, 2002, North central Arizona water demand study: Phase 1, draft report.

Ross, L.E., Springer, A.E., 2003, Three-dimensional groundwater modeling of the Redwall - Muav Aquifer on the Kaibab Plateau, north rim of the Grand Canyon, Arizona, based on newly collected data sets: Geological Society of America, Abstracts with Programs, vol. 35; 6, p. 373.

Ross, L.E. and A.E. Springer, 2003, Roaring Springs, Grand Canyon, Arizona: New data sets provide tools for improved recharge area delineation: 16th Annual Symposium of the Arizona Hydrological Society, September 18-19, 2003, Mesa, AZ.

Rote, J.J., Flynn, M.E., and Bills, D.J., 1997, Hydrologic data, Colorado River and major tributaries, Glen Canyon Dam to Diamond Creek, Arizona, water years 1990-1995: USGS Open–File Report 97-250, 474 p.

Rust Engineering Co., 1970, Preliminary study development of water resources, Kaibab - Paiute Indian Reservation, Arizona: US Dept. of Commerce, Economic Development Administration Report, 23 pp.

Sabol, T.A., Springer, A.E., Umhoefer, P.J., 2002, Affect of the Sevier-Toroweap fault on ground-water modeling of the Kaibab Paiute Reservation, northern Arizona: Geological Society of America, Rocky Mountain Section: Abstracts with Programs, vol. 34, 4, p. 15.

Sabol, T. A., and Springer, A. E., 2003, Delineation of source water protection areas for tribal water supplies, Kaibab Paiute reservation, Arizona: Geological Society of America Abstracts with Programs, vol. 35.

Semmens, B.A., 1999, Hydrogeologic characterization and numerical transport simulations of a reattachment-bar aquifer in the Colorado River: Northern Arizona University, M.S. thesis, 188 pp.

Springer, A.E., Petroutson, W.D., and Blakely, J.C., 1996, Hydraulic conductivity variability of a Colorado River reattachment bar induced by a controlled flood: EOS, Transactions of the American Geophysical Union, v. 77, 46, p. 272-273.

Springer, A.E., Bills, D., 1998, Exploration for and ecological importance of shallow and deep ground-water around San Francisco Mountain: in Geologic Excursions in Northern and Central Arizona, Duebendorfer, E.M., (ed.), p. 27-33.

Springer, A.E., Petroutsen, W.D., Semmens, B.A., 1999, Spatial and temporal variability of hydraulic conductivity in active reattachment bars of the Colorado River, Grand Canyon: Ground Water, vol. 37, p. 338-344.

Stevens, L.E., Schmidt, J.C., Ayers, T.J., Brown, B.T., 1995, Flow regulation, geomorphology and Colorado River marsh development in the Grand Canyon, Arizona: Ecological Applications 5:1025-1039.

Stevens, L.E., Shannon, J.P., and Blinn, D.W., 1997, Colorado River benthic ecology in Grand Canyon Arizona, USA: dam, tributary and geomorphological influences: Regulated Rivers: Research and Management 13:129-149.

Topping, D.J., Schmidt, J.C., and Vierra, L.E., Jr., 2003, Computation and analysis of the instantaneous discharge record for the Colorado River at Lees Ferry, Arizona, May 8, 1921, through September 30, 2000: U.S. Geological Survey Professional Paper 1677.

Truini, M., 2004, Preliminary Investigation of Structural Controls of Ground-Water in Pipe Spring National Monument, Arizona: USGS Scientific Investigations Report 2004-5082.

Truini, M., 2002, Movement and age of groundwater in the Navajo Sandstone and Kayenta Formation in the area of Pipe Spring National Monument, northern Arizona: in Abstracts with Programs: Geological Society of America 54th Annual Meeting, May 2002, Cedar City, Utah, vol. 34, no. 4, p. A17.

Ward, J., 2002, Groundwater on the Plateau: Southwest Hydrology, Vol.1, No. 4.

Webb, R.H., Smith, S.S. and McCord, A.S., 1991, Historic channel change of Kanab Creek, southern Utah and northern Arizona: Grand Canyon Natural History Association, Monograph no. 9, 91 pp.

Wilson, E., 2000, Geologic framework and numerical groundwater models of the south rim of the Grand Canyon, Arizona: Northern Arizona University, M.S. thesis, 72 pp.

Wilson, E.S., Springer, A.E., Winter, C.L., 1999, Delineating spring capture zones for the south rim of the Grand Canyon, Arizona, using framework and numerical models: Geological Society of America, Abstracts with Programs, vol. 31, 7, pp.

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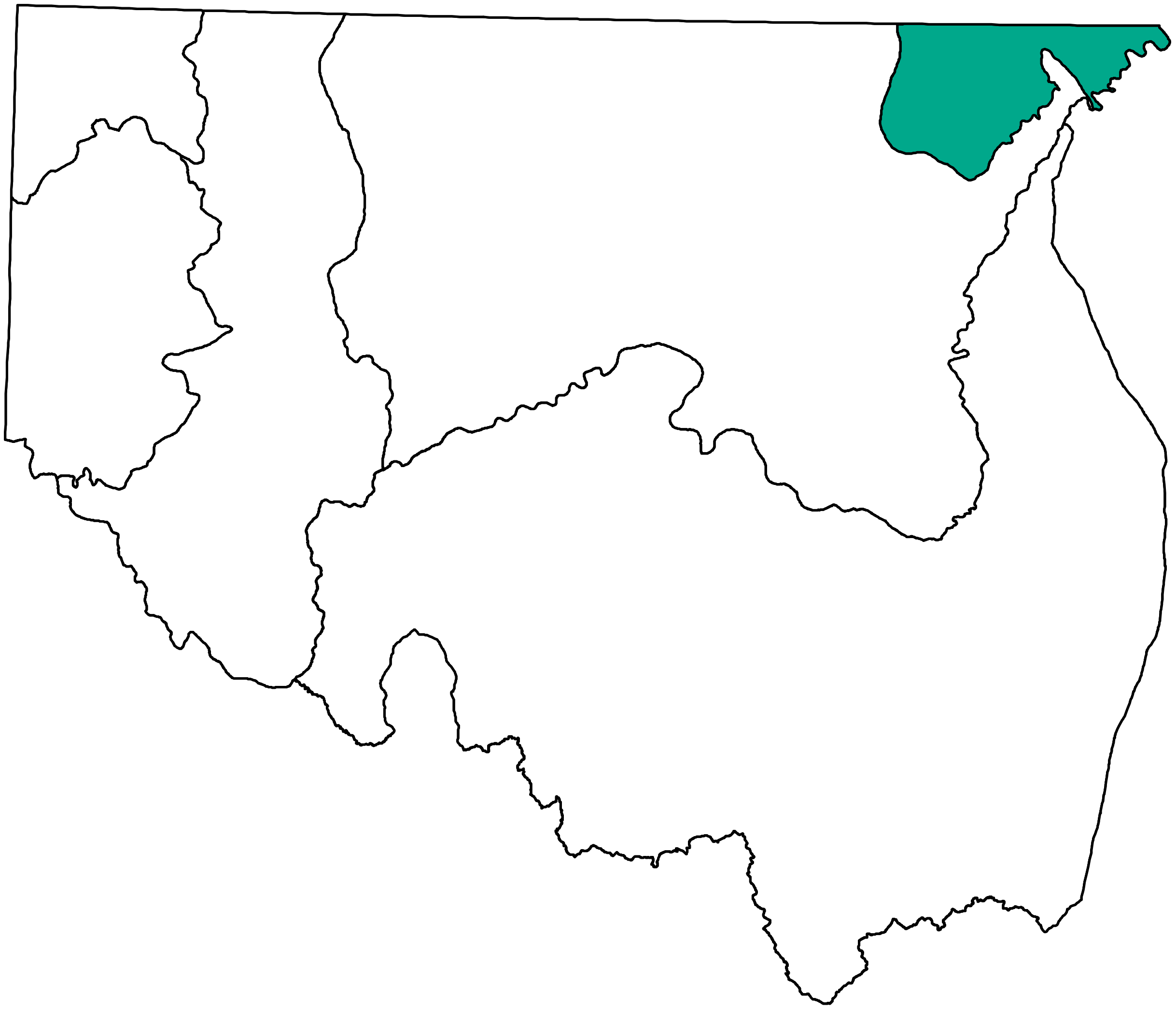
Section 6.4
Paria Basin



6.4.1 Geography of the Paria Basin

The Paria Basin, located in the northeastern part of the planning area is 408 square miles in area, the smallest basin in the planning area. Geographic features and principal communities are shown on Figure 6.4-1. The basin is characterized by a plateau and canyons. Vegetation types include Great Basin desertscrub and Great Basin conifer woodland. (See Figure 6.0-9)

- Principal geographic features shown on Figure 6.4-1 are:
    - Principal basin community of Wahweap
    - The Paria Plateau
    - Paria River in the north central portion of the basin
    - Lake Powell on the eastern basin boundary
- Not well shown on Figure 6.4-1 are the Vermilion Cliffs, which form the southern basin boundary and the highest point in the basin at 7,326 feet.

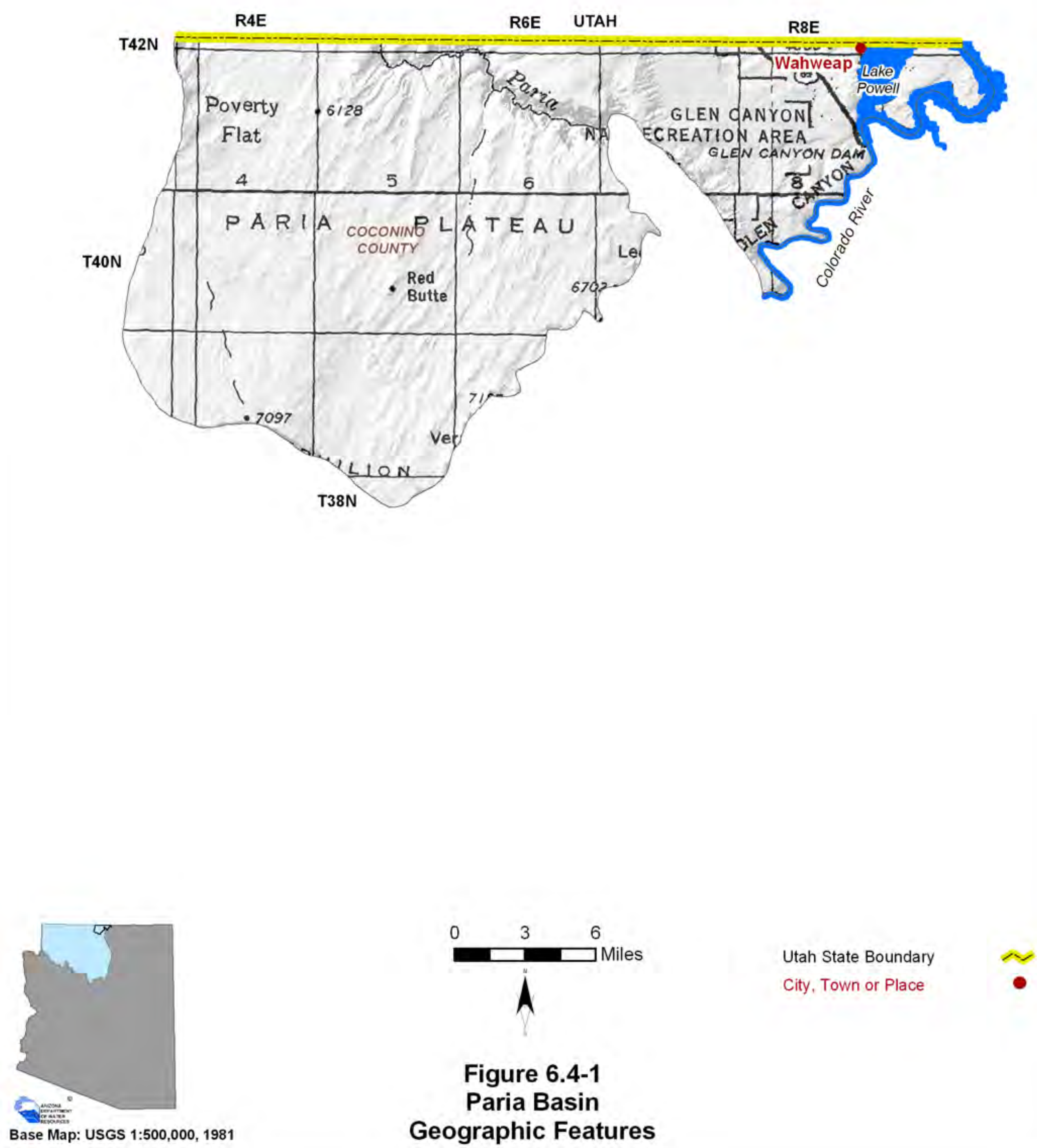


Figure 6.4-1
Paria Basin
Geographic Features

6.4.2 Land Ownership in the Paria Basin

Land ownership, including the percentage of ownership by category, for the Paria Basin is shown in Figure 6.4-2. The principal feature of land ownership in this basin is the large portion of land, 86% of the total basin area, in the Vermilion Cliffs National Monument. A description of land ownership data sources and methods is found in Volume 1, Section 1.3.8. Land ownership categories are discussed below in the order of percentage from largest to smallest in the basin.

U.S. Bureau of Land Management (BLM)

- 83.7% of the land is federally owned and managed by the Arizona Strip Field Office of the Bureau of Land Management.
- Most of the BLM land in the basin is within the Vermilion Cliffs National Monument and includes a portion of the 79,000 acre Vermilion Cliffs Wilderness.
- Land uses include resource conservation, recreation and grazing.

National Park Service (NPS)

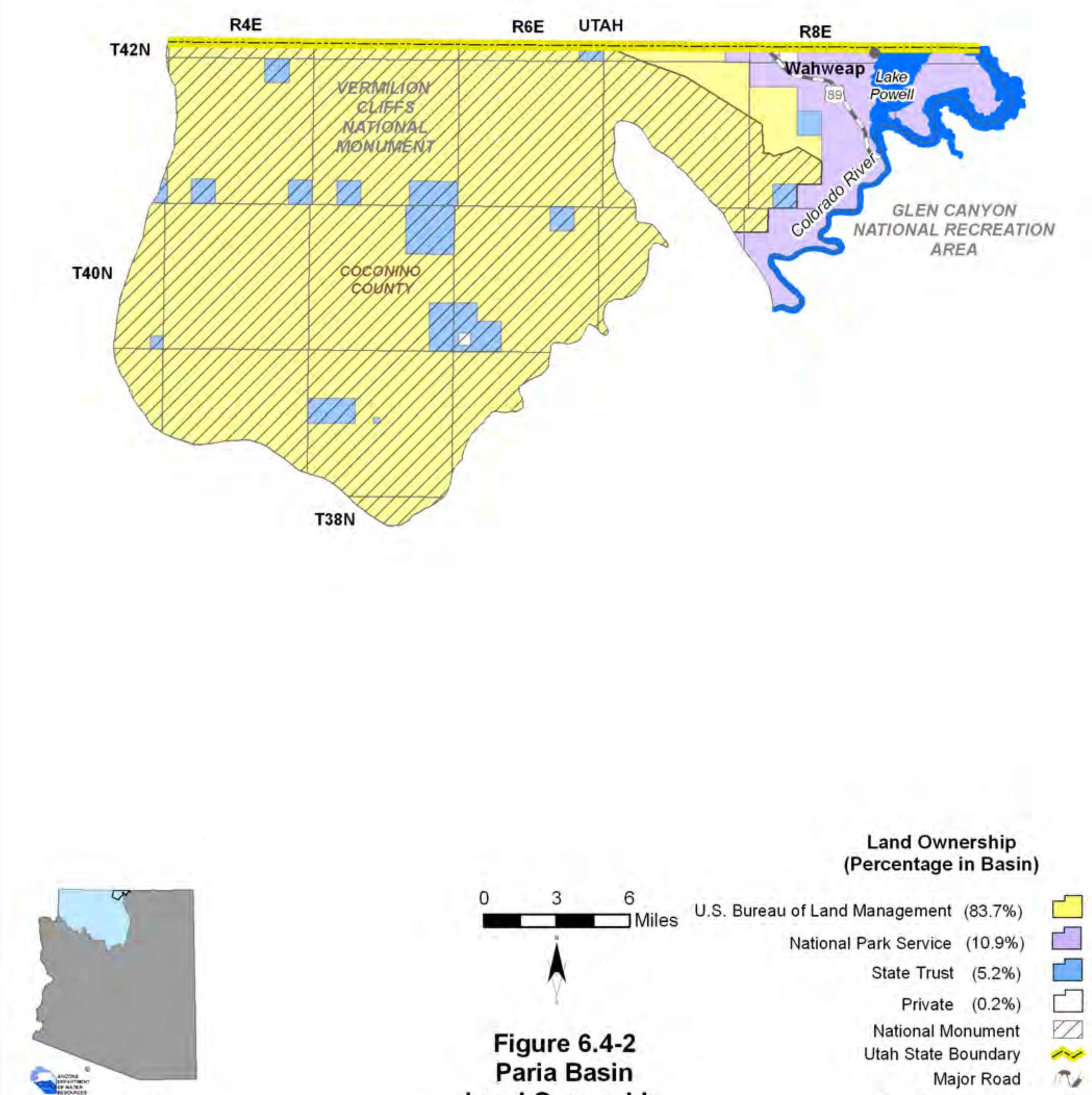
- 10.9% of the land is federally owned and managed by the National Park Service as the Glen Canyon National Recreation Area.
- Primary land use is recreation.

State Trust Land

- 5.2% of the land is held in trust for the public schools under the State Trust Land system.
- State land is located throughout the basin interspersed with BLM land.
- Primary land use is grazing.

Private

- 0.2% of the land is private, consisting of two small parcels.
- Private land is located in the vicinity of Wahweap and surrounded by state trust land in the central portion of the basin.
- Land uses include domestic, commercial and ranching.



Source: ALRIS, 2004
Bureau of Land management, 1999 & 2000

Figure 6.4-2
Paria Basin
Land Ownership

6.4.3 Climate of the Paria Basin

Climate data from NOAA/NWS Co-op Network and Evaporation Pan stations are complied in Table 6.4-1 and the locations are shown on Figure 6.4-3. Figure 6.4-3 also shows precipitation contour data from the Spatial Climate Analysis Service (SCAS) at Oregon State University. The Paria Basin does not contain AZMET or SNOTEL/ Snowcourse stations. A description of the climate data sources and methods is found in Volume 1, Section 1.3.3.

NOAA/NWS Co-op Network

- Refer to Table 6.4-1A
- Temperatures at the one NOAA/NWS Co-op Network station range from an average annual high of 84.5°F to an average annual low of 37.5°F.
- The highest average seasonal rainfall occurs in the summer season (July-September) when 30% of the annual rainfall occurs. Average annual rainfall is 6.78 inches.

Evaporation Pan

- Refer to Table 6.4-1B
- There is one evaporation pan station in the basin. This pan is at 3,720 feet and has an average annual evaporation rate of 100.18 inches.

SCAS Precipitation Data

- See Figure 6.4-3
- Additional precipitation data shows average annual rainfall as high as 16 inches in the southern portion of the basin and as low as four inches along the Colorado River.

Table 6.4-1 Climate Data for the Paria Basin

A. NOAA/NWS Co-op Network:

Station Name	Elevation (in feet)	Period of Record Used for Averages	Average Temperature Range (in F)		Average Precipitation (in inches)				
			Max/Month	Min/Month	Winter	Spring	Summer	Fall	Annual
Wahweap	3,730	1971-2000	84.5/Jul	37.5/Jan	1.70	1.09	2.02	1.97	6.78

Source: WRCC, 2003
Notes:
[1]Average temperature for period of record shown; average precipitation from 1971-2000

B. Evaporation Pan:

Station Name	Elevation (in feet)	Period of Record Used for Averages	Avg. Annual Evap (in inches)
Wahweap	3,720	1961 - 2000	100.18

Source: WRCC, 2003

C. AZMET:

Station Name	Elevation (in feet)	Period of Record Used for Averages	Average Annual Reference Evaportranspiration, in inches (*Number of years to calculate averages*)
None			

Source: Arizona Meteorological Network, 2005

D. SNOTEL/Snowcourse:

Station Name	Elevation (in feet)	Period of Record Used for Averages	Average Snowpack, at Beginning of the Month, as Inches Snow Water Content *(Number of measurements to calculate average)*					
			Jan.	Feb.	March	April	May	June
None								

Source: NRCS, 2005

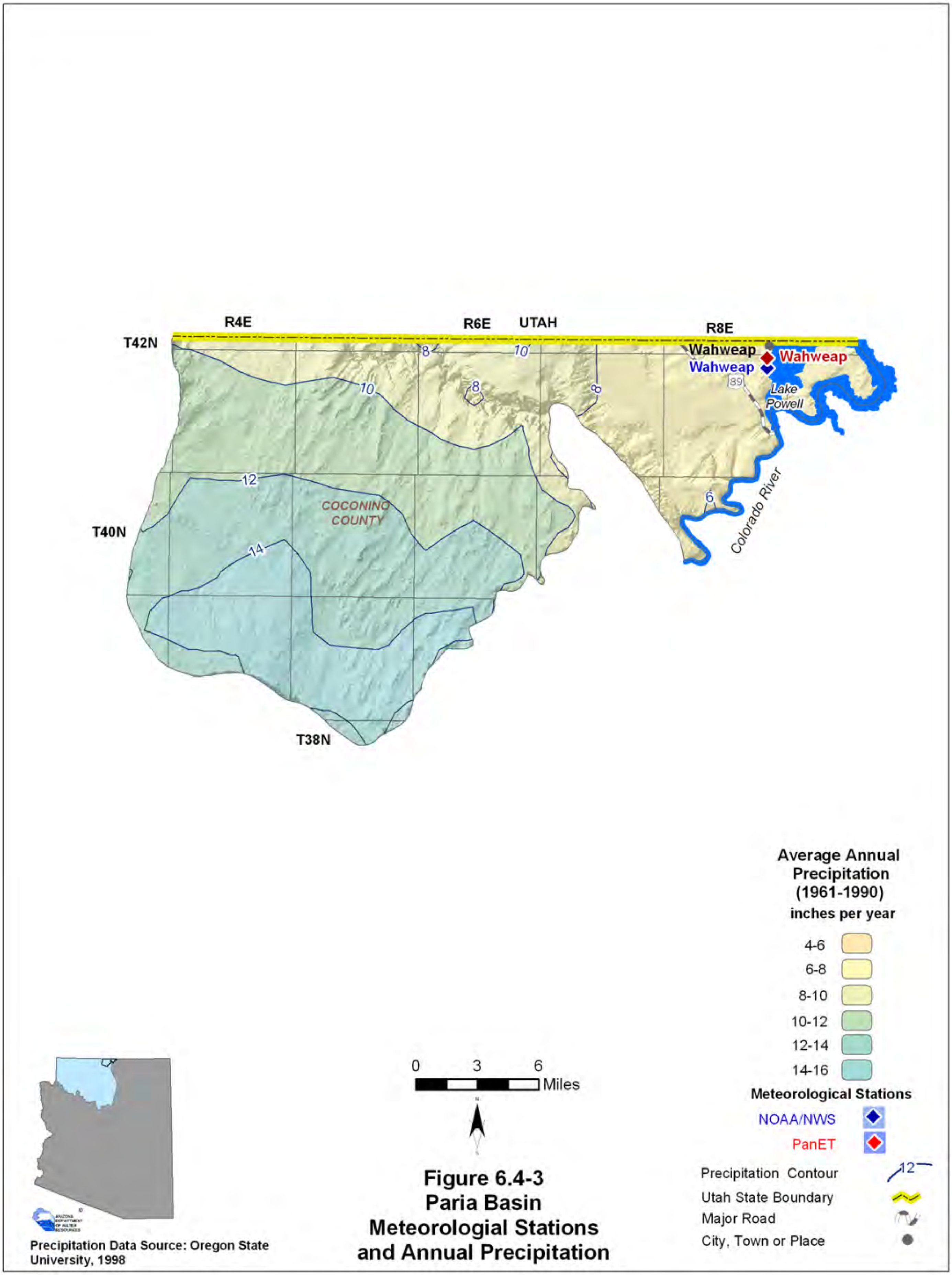


Figure 6.4-3
Paria Basin
Meteorologial Stations and Annual Precipitation

6.4.4 Surface Water Conditions in the Paria Basin

There are no streamflow data or flood ALERT equipment in this basin. Reservoir and stockpond data, including maximum storage or maximum surface area, are shown in Table 6.4-4. The USGS runoff contours and large reservoirs are shown on Figure 6.4-4. A description of stream data sources and methods is found in Volume 1, Section 1.3.16. A description of reservoir data sources and methods is found in Volume 1, Section 1.3.11. A description of stockpond data sources and methods is found in Volume 1, Section 1.3.15.

Reservoirs and Stockponds

- Refer to Table 6.4-4.
- The only large reservoir in the basin is Lake Powell with a maximum storage capacity of 20.3 million acre-feet. Most of the storage is in Utah.
- Lake Powell is used for hydroelectric, irrigation, recreation and other uses.
- There are 57 registered stockponds in this basin.

Runoff Contour

- Refer to Figure 6.4-4.
- Average annual runoff is highest, 0.5 inches per year or 26 acre-feet per square mile, in the southwestern portion and decreases to 0.1 inches, or five acre-feet per square mile, in the eastern portion of the basin.

Table 6.4-2 Streamflow Data for the Paria Basin

Station Number	USGS Station Name	Drainage Area (in mi^2)	Mean Basin Elevation (in feet)	Period of Record	Average Seasonal Flow (% of annual flow)				Annual Flow/Year (in acre-feet)				Years of Record
					Winter	Spring	Summer	Fall	Minimum	Median	Mean	Maximum	
None													

Sources: USGS NWIS, USGS 1998 and USGS 2003.

Table 6.4-3 Flood ALERT Equipment in the Paria Basin

Station ID	Station Name	Station Type	Install Date	Responsibility
None				

Table 6.4-4 Reservoirs and Stockponds in the Paria Basin

A. Large Reservoirs (500 acre-feet capacity and greater)

MAP KEY	RESERVOIR/LAKE NAME *(Name of dam, if different)*	OWNER/OPERATOR	MAXIMUM STORAGE (AF)	USE[1]	JURISDICTION
1	Powell (Glen Canyon Dam)	Bureau of Reclamation	20,325,000	H,I,O,R	Federal

Source: US Army Corps of Engineers, 2005

B. Other Large Reservoirs (50 acre surface area or greater)

MAP KEY	RESERVOIR/LAKE NAME *(Name of dam, if different)*	OWNER/OPERATOR	MAXIMUM SURFACE AREA (acres)	USE	JURISDICTION
None identified by ADWR at this time					

C. Small Reservoirs (greater than 15 acre-feet and less than 500 acre-feet capacity)

Total number: 0
Total maximum storage: 0 acre-feet

D. Other Small Reservoirs (between 5 and 50 acres surface area)

Total number: 0
Total surface area: 0 acres

E. Stockponds (up to 15 acre-feet capacity)

Total number: 57

[1] H=hydroelectric; I=irrigation; O=other; R=recreation

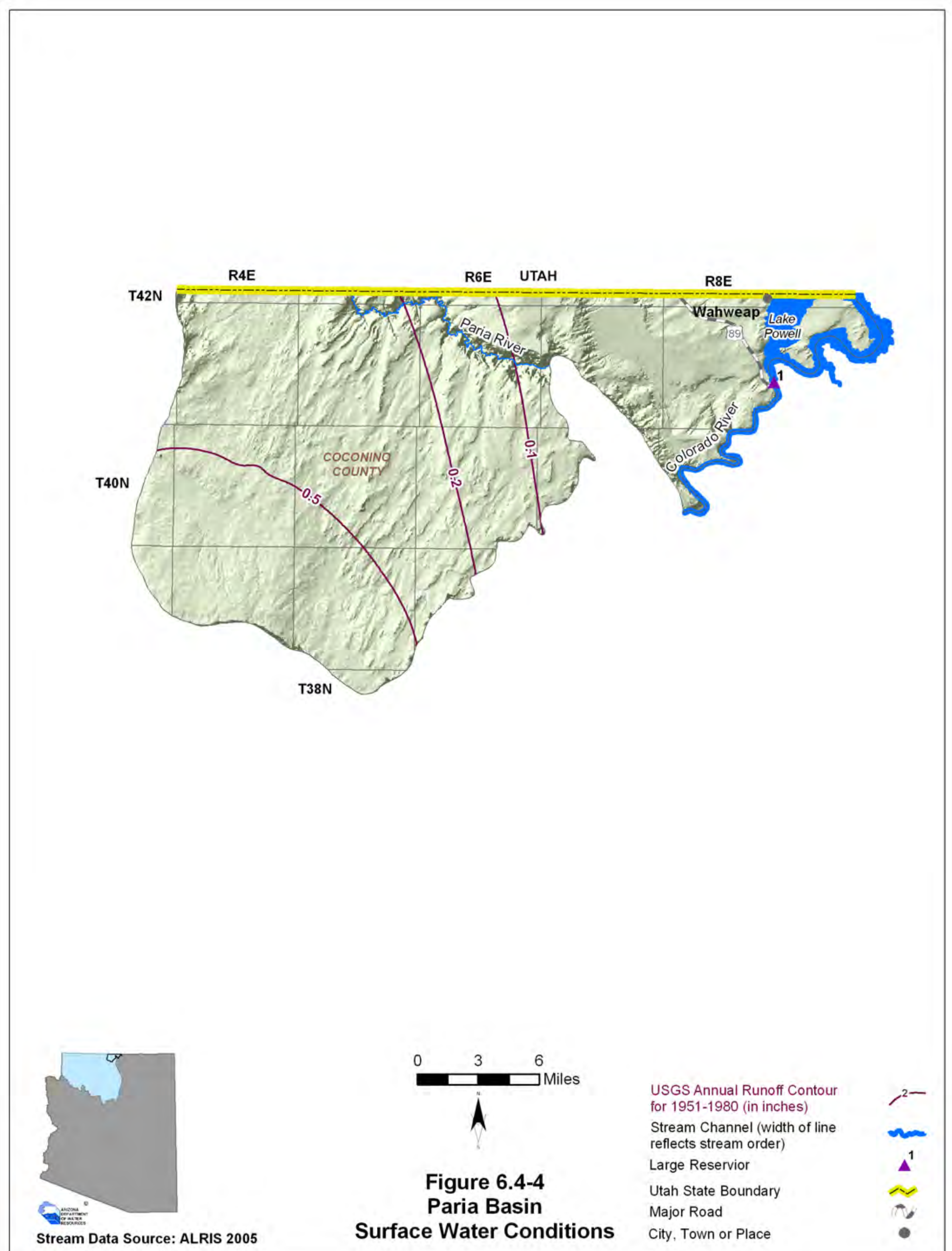


Figure 6.4-4
Paria Basin
Surface Water Conditions

6.4.5 Perennial/Intermittent Streams and Major Springs in the Paria Basin

The total number of springs in the basin are shown in Table 6.4-5. The locations of perennial streams are shown on Figure 6.4-5. A description of data sources and methods for intermittent and perennial reaches is found in Volume 1, Section 1.3.16. A description of spring data sources and methods is found in Volume 1, Section 1.3.14.

- There are no intermittent streams and the only perennial streams are the Colorado River and the Paria River.
- There are no major or minor springs.
- The total number of springs, regardless of discharge, identified by the USGS varies from 2 to 3, depending on the database reference.

Table 6.4-5 Springs in the Paria Basin

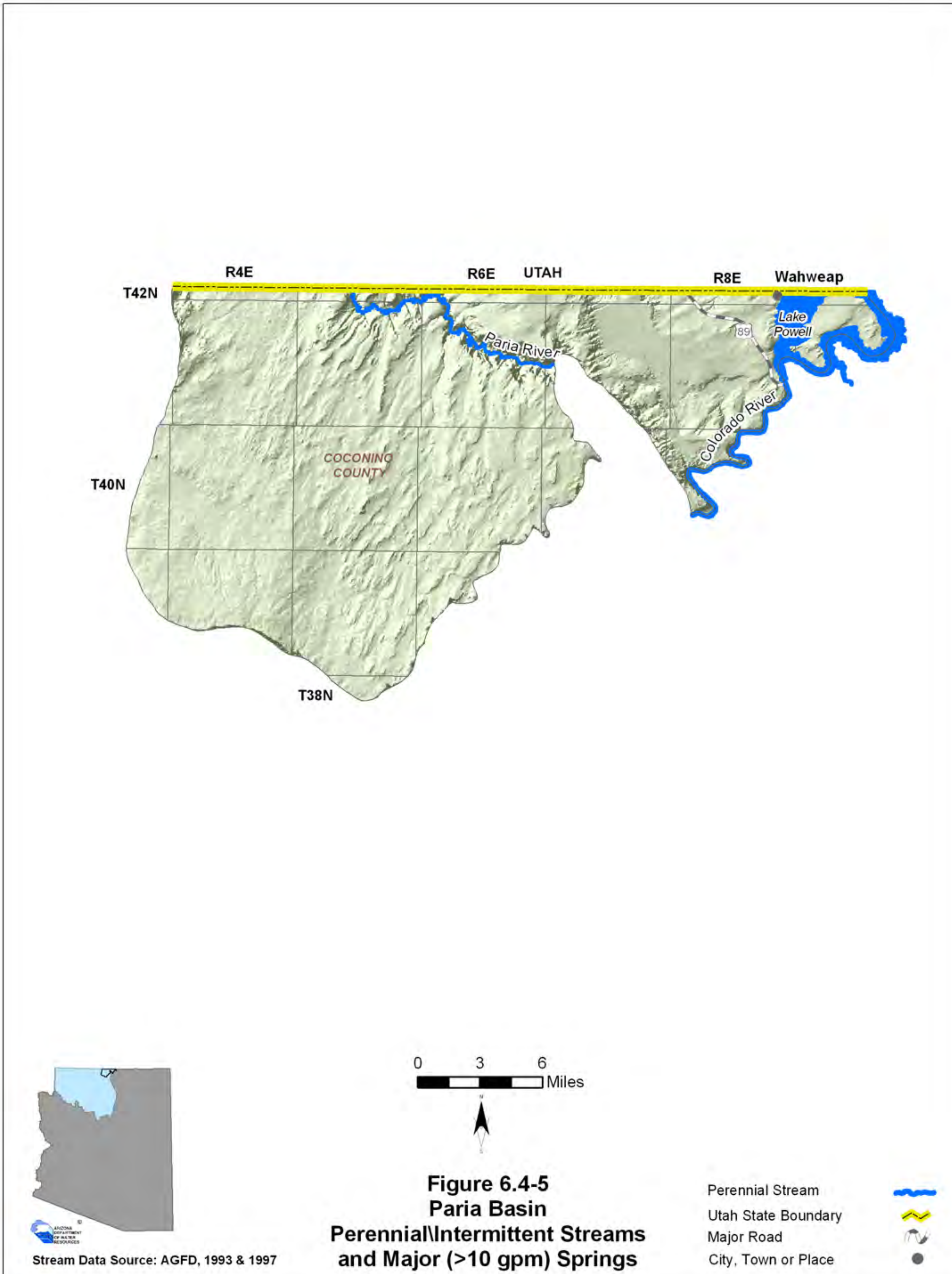
A. Major Springs (10 gpm or greater):

Map Key	Name	Location		Discharge (in gpm)	Date Discharge Measured
		Latitude	Longitude		
None identified by ADWR at this time					

B. Minor Springs (1 to 10 gpm):

Name	Location		Discharge (in gpm)	Date Discharge Measured
	Latitude	Longitude		
None identified by ADWR at this time				

C. Total number of springs, regardless of discharge, identified by USGS (see ALRIS, 2005 and NHD, 2006): 2 to 3



Stream Data Source: AGFD, 1993 & 1997

Figure 6.4-5
Paria Basin
Perennial\Intermittent Streams and Major (>10 gpm) Springs

6.4.6 Groundwater Conditions of the Paria Basin

Major aquifers, well yields, estimated water in storage, number of index wells and date of last water-level sweep are shown in Table 6.4-6. Figure 6.4-6 shows water-level change between 1990-1991 and 2003-2004. Figure 6.4-7 contains hydrographs for selected wells shown on Figure 6.4-6. Figure 6.4-8 shows well yields in two yield categories. A description of aquifer data sources and methods is found in Volume 1, Section 1.3.2. A description of well data sources and methods, including water-level changes and well yields, is found in Volume 1, Section 1.3.19.

Major Aquifers

- Refer to Table 6.4-6 and Figure 6.4-6.
- The major aquifer in the basin is sedimentary rock (N Aquifer).
- Almost all of the basin geology consists of consolidated crystalline and sedimentary rock.
- Data on groundwater flow direction is not available for this basin.

Well Yields

- Refer to Table 6.4-6 and Figure 6.4-8.
- As shown on Figure 6.4-8, well yields in this basin range from less than 100 gallons per minute (gpm) to 1,000 gpm. All well yield data is from the northeastern portion of the basin near Wahweap.
- One source of well yield information, based on three reported wells, indicates that the median well yield in this basin is 520 gpm in the vicinity of Wahweap.

Water in Storage

- Refer to Table 6.4-6.
- There is one estimate of water in storage for this basin. This estimate, from a 1994 ADWR study, indicates there is 1,500,000 acre-feet of water in storage to a depth of 1,200 feet.

Water Level

- Refer to Figure 6.4-6. Water levels are shown for a well measured in 2003-2004.
- The Department annually measures one index well in this basin; this well has a depth to water of 483 feet.
- A hydrograph corresponding to the well found on Figure 6.3-6 is shown in Figure 6.3-7.

Table 6.4-6 Groundwater Data for the Paria Basin

Basin Area (in square miles):	408	
Major Aquifer(s):	**Name and/or Geologic Units**	
	Sedimentary Rock (N Aquifer)	
Well Yields, in gal/min:	N/A	Measured by ADWR and/or USGS
	Range 30-600 Median 520 (3 wells reported)	Reported on registration forms for large (> 10-inch) diameter wells
	Range 30-1,400	ADWR (1990 and 1994)
	Range 0-500	USGS (1994)
Estimated Natural Recharge, in acre-feet/year:	N/A	
Estimated Water Currently in Storage, in acre-feet:	1,500,000 (to 1,200 ft)	ADWR (1994)
	N/A	Arizona Water Commission (1975)
Current Number of Index Wells:	1	
Date of Last Water-level Sweep:	1976 (34 wells measured)	

N/A = Not Available

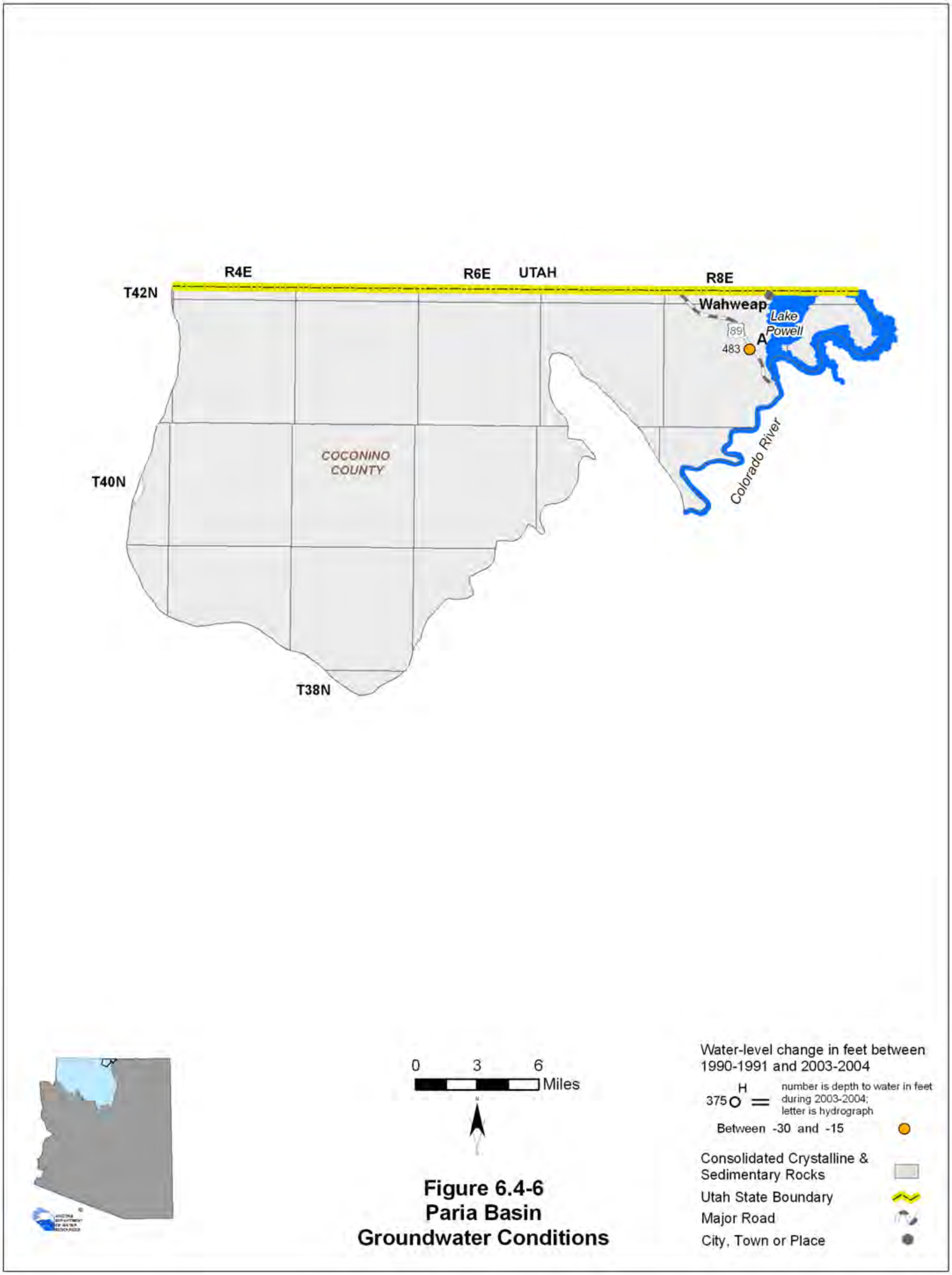
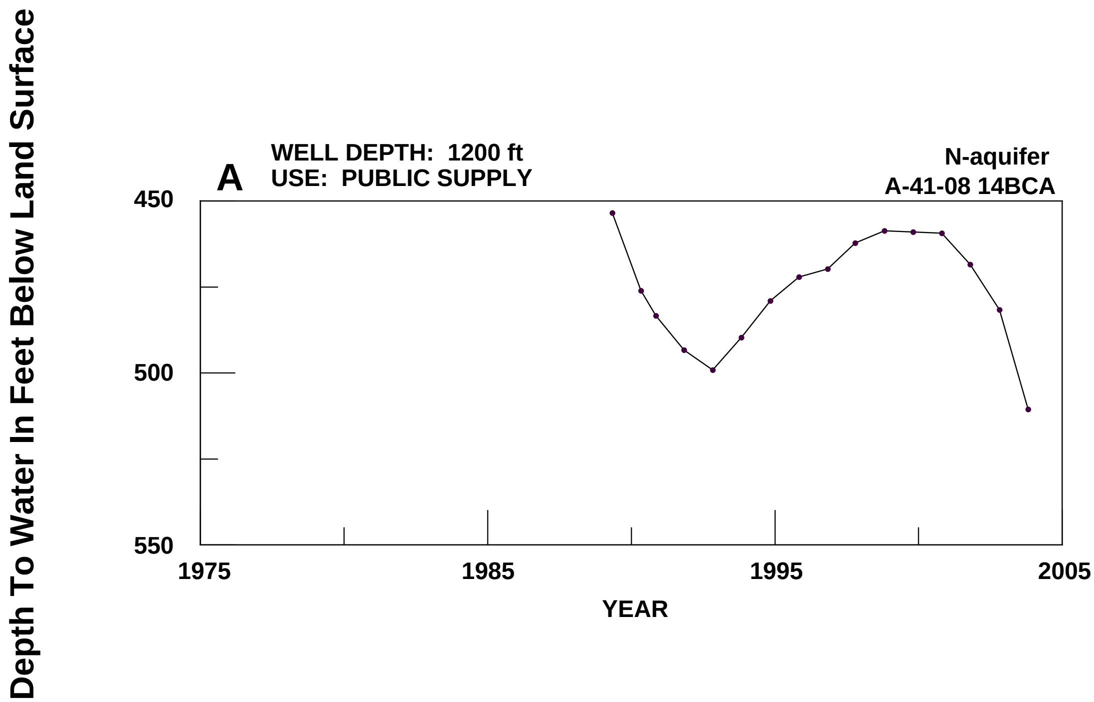


Figure 6.4-6
Paria Basin
Groundwater Conditions

Figure 6.4-7
Paria Basin
Hydrographs Showing Depth to Water in Selected Wells



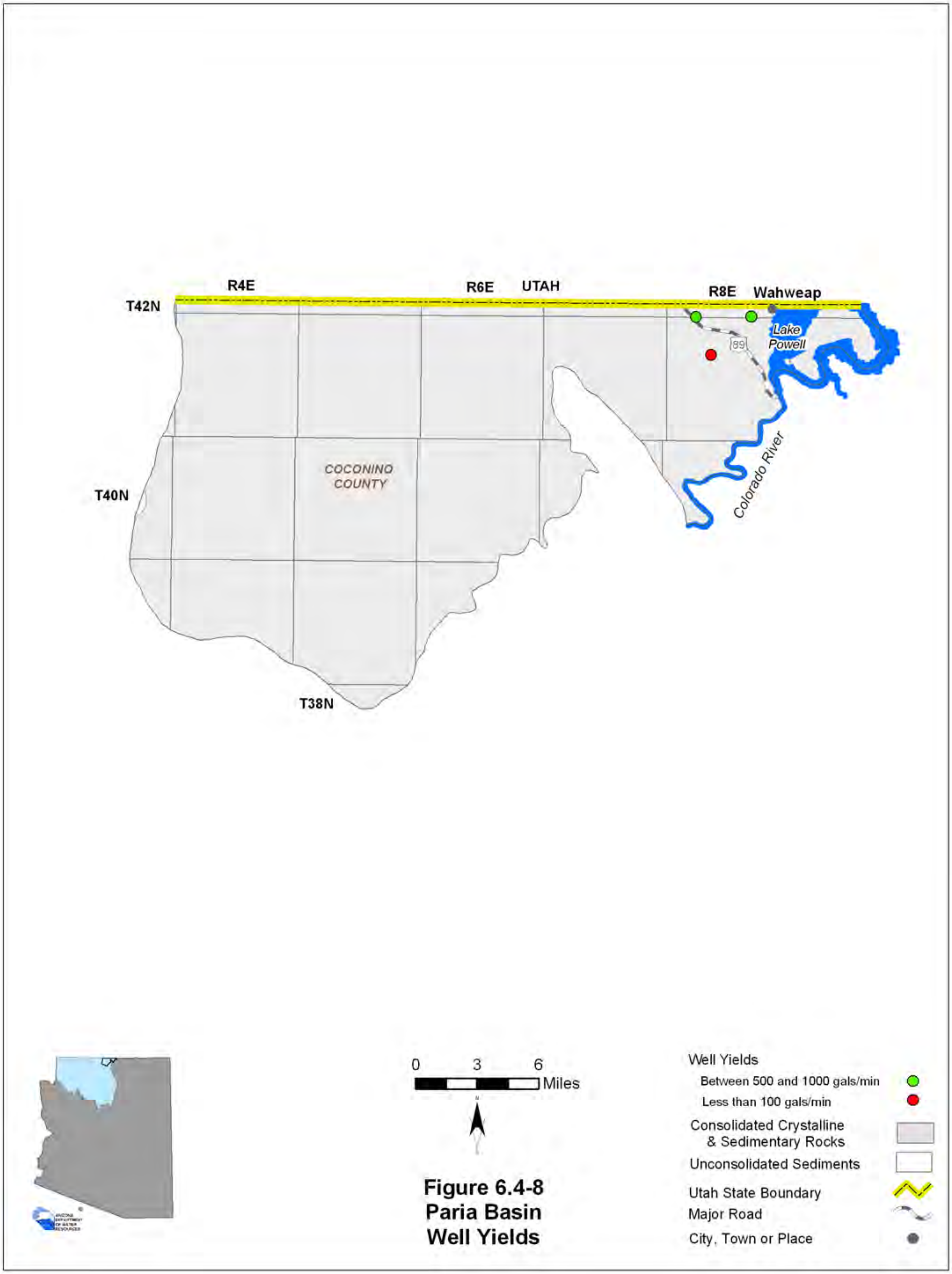


Figure 6.4-8
Paria Basin
Well Yields

6.4.7 Water Quality of the Paria Basin

Wells, springs and mine sites with parameter concentrations that have equaled or exceeded drinking water standard(s), including location and parameter(s) are shown in Table 6.4-7A. Impaired lakes and streams with site type, name, length of impaired reach, area of impaired lake, designated use standard and parameter(s) exceeded is shown in Table 6.4-7B. Figure 6.4-9 shows the location of water quality occurrences keyed to Table 6.4-7. A description of water quality data sources and methods is found in Volume 1, Section 1.3.18. Not all parameters were measured at all sites; selective sampling for particular constituents is common.

Wells, Springs and Mines

- Refer to Table 6.4-7A.
- Seven wells have parameter concentrations that have equaled or exceeded the drinking water standard for arsenic.

Lakes and Streams

- Refer to Table 6.4-7B.
- The water quality standard for suspended sediment concentration was exceeded in one 29-mile stream reach, the Paria River from the Utah border to the Colorado River. A portion of this impaired reach is located in the Kanab Plateau Basin.
- This reach is not part of the ADEQ water quality improvement effort called the Total Maximum Daily Load (TMDL) Program at this time.

Table 6.4-7 Water Quality Exceedences in the Paria Basin[1]

A. Wells, Springs and Mines

Map Key	Site Type	Site Location			Parameter(s) Concentration has Equaled or Exceeded Drinking Water Standard (DWS)[2]
		Township	Range	Section	
1	Well	42 North	8 East	32	As
2	Well	42 North	8 East	35	As
3	Well	42 North	8 East	35	As
4	Well	42 North	8 East	36	As
5	Well	41 North	8 East	4	As
6	Well	41 North	8 East	14	As
7	Well	41 North	8 East	14	As

B. Lakes and Streams

Map Key	Site Type	Site Name	Length of Impaired Stream Reach (in miles)	Area of Impaired Lake (in acres)	Designated Use Standard[3]	Parameter(s) Exceeding Use Standard[2]
a	Stream	Paria River (Utah border to Colorado River)	29[4]	NA	A&W	SSC

Notes:

NA = Not Applicable
[1] Water quality samples collected between 1977 and 2001.
[2] As = Arsenic
SSC = Suspended Sediment Concentration
[3] A&W = Aquatic and Wildlife
[4] Total length of the impaired reach. A portion of this reach is in the Kanab Plateau Basin.

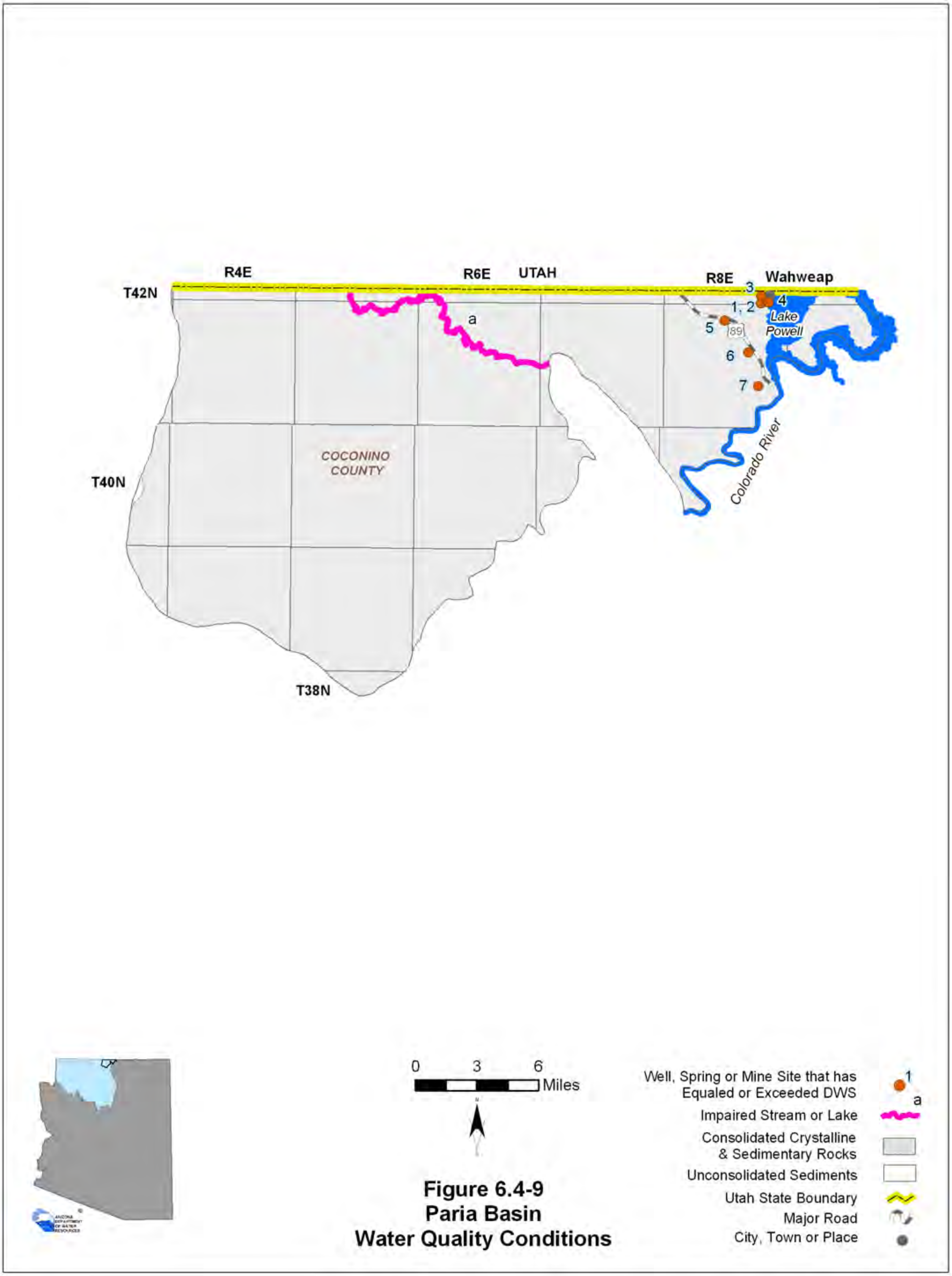


Figure 6.4-9
Paria Basin
Water Quality Conditions

6.4.8 Cultural Water Demands in the Paria Basin

Cultural water demand data including population, number of wells and the average well pumpage and surface water diversions by the municipal, industrial and agricultural sectors are shown in Table 6.4-8. There is no recorded effluent generation in this basin. Figure 6.4-10 shows the location of demand centers. A description of cultural water demand data sources and methods is found in Volume 1, Section 1.3.5. More detailed information on cultural water demands is found in Section 6.0.7.

Cultural Water Demands

- Refer to Table 6.4-8 and Figure 6.4-10.
- Population in this basin increased from 237 in 1980 to 555 in 2000 and is projected to increase to 703 in 2050.
- All water use is for municipal demand in the vicinity of Wahweap.
- Groundwater demand was reported as 1,000 acre-feet per year on average from 1971-1990 and less than 300 acre-feet per year on average from 1991-2003.
- There is no reported surface water use in this basin.
- As of 2003 there were 12 registered wells with a pumping capacity of less than or equal to 35 gallons per minute and 3 wells with a pumping capacity of more than 35 gallons per minute.

Table 6.4-8 Cultural Water Demands in the Paria Basin[1]

Year	Recent (Census) and Projected (DES) Population	Number of Registered Water Supply Wells Drilled		Average Annual Demand (in acre-feet)						
				Well Pumpage			Surface-Water Diversions			Data Source
		Q ≤ 35 gpm	Q > 35 gpm	Municipal	Industrial	Irrigation	Municipal	Industrial	Irrigation	
1971										
1972										
1973					1,000			NR		
1974										
1975		12[2]	3[2]							
1976										
1977										
1978					1,000			NR		
1979										
1980	237									
1981	262									ADWR (1994)
1982	287									
1983	312	0	0		1,000			NR		
1984	337									
1985	362									
1986	387									
1987	412									
1988	437	0	0		1,000			NR		
1989	462									
1990	487									
1991	494									
1992	500									
1993	507	0	0	<300	NR	NR		NR		
1994	514									
1995	521									
1996	528									
1997	535									USGS (2005)
1998	541	0	0	<300	NR	NR		NR		
1999	548									
2000	555									
2001	562									
2002	570	0	0	<300	NR	NR		NR		
2003	577									
2010	623									
2020	638									
2030	647									
2040	656									
2050	703									
WELLS TOTALS:		**12**	**3**							

[1] Does not include evaporation losses from stockponds and reservoirs.
[2] Includes all wells through 1980.
NR - Not reported

Table 6.4-9 Effluent Generation in the Paria Basin

Facility Name	Ownership	City/Location Served	Population Served	Volume Treated/Generated (acre-feet)	Disposal Method								Current Treatment Level	Population Not Served	Year of Record
					Water-course	Evaporation Pond	Irrigation	Golf Course	Municipal Reuse	Wildlife Area	Discharged to Another Facility	Infiltration Basins			
No Wastewater Treatment Facilities Identified by ADWR in this Basin															

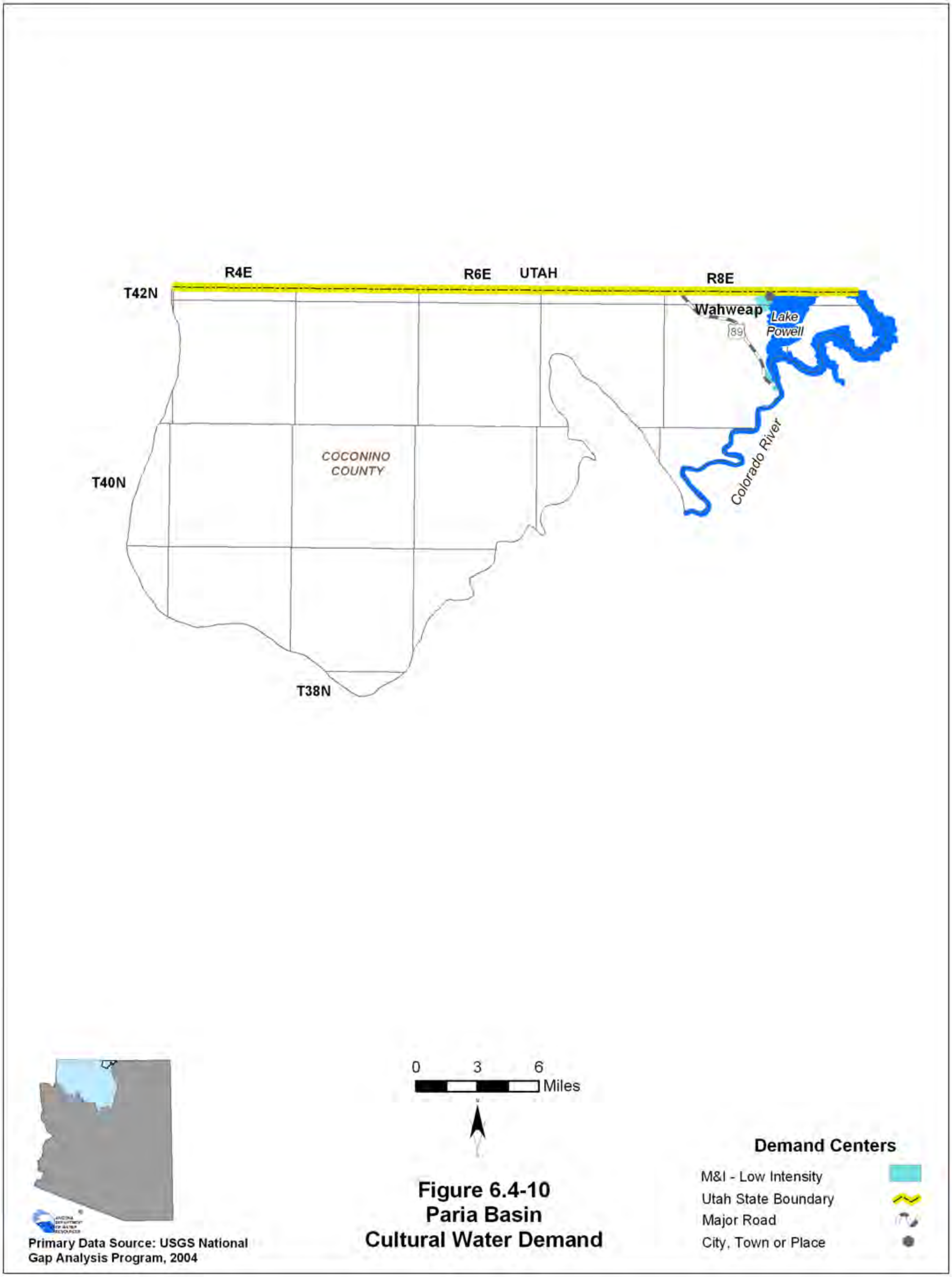


Figure 6.4-10
Paria Basin
Cultural Water Demand

6.4.9 Water Adequacy Determinations in the Paria Basin

Water adequacy determination information including the subdivision name, location, number of lots, adequacy determination, reason for the inadequacy determination, date of determination and subdivision water provider are shown in Table 6.4-10. Figure 6.4-11 shows the locations of subdivisions keyed to the Table. A description of the Water Adequacy Program is found in Volume 1, Appendix A. Adequacy determination data sources and methods are found in Volume 1, Sections 1.3.1.

Water Adequacy Reports

- See Table 6.4-10
- All subdivisions reviewed for an adequacy determination are in Coconino County in the vicinity of Wahweap. Six water adequacy determinations for 991 lots total have been made in this basin through May, 2005, and all were determined to be adequate.

Table 6.4-10 Adequacy Determinations in the Paria Basin

Map Key	Subdivision Name	County	Location			No. of Lots	ADWR File No.[2]	ADWR Adequacy Determination	Reason(s) for Inadequacy Determination[3]	Date of Determination	Water Provider at the Time of Application
			Township	Range	Section						
1	Greenehaven	Coconino	42 North	8 East	32	770		Adequate		12/28/77	Greenehaven Development Corporation
2	Greenehaven # 4	Coconino	42 North	8 East	32	12		Adequate		06/03/88	Greenehaven Water Company
4	Greenehaven # 5	Coconino	42 North	8 East	32	86	22-400507	Adequate		07/03/01	Greenehaven Water Company
3	Greenehaven # 6	Coconino	42 North	8 East	32	83	22-400505	Adequate		07/03/01	Greenehaven Water Company
5	Greenehaven Mobile Home Estates	Coconino	42 North	8 East	32	NA		Adequate		07/08/81	Greenehaven Water Company
6	Patio Homes at Lake Powell	Coconino	42 North	8 East	32	40	22-400698	Adequate		04/02/02	Greenehaven Water Company

Notes:

[1]Each determination of the adequacy of water supplies available to a subdivision is based on the information available to ADWR and the standards of review and policies in effect at the time the determination was made. In some cases, ADWR might make a different determination if a similar application were submitted today, based on the hydrologic data and other information currently available, as well as current rules and policies.

[2] Prior to February 1995, ADWR did not assign file numbers to applications for adequacy determination.

[3] A. Physical/Continuous
1) Insufficient Data (applicant chose not to submit necessary information, and/or available hydrologic data insufficient to make determination)
2) Insufficient Supply (existing water supply unreliable or physically unavailable;for groundwater, depth-to-water exceeds criteria)
3) Insufficient Infrastructure (distribution system is insufficient to meet demands or applicant proposed water hauling)
B. Legal (applicant failed to demonstrate a legal right to use the water or failed to demonstrate the provider's legal authority to serve the subdivision)
C. Water Quality
D. Unable to locate records

NA = Not available to ADWR at this time

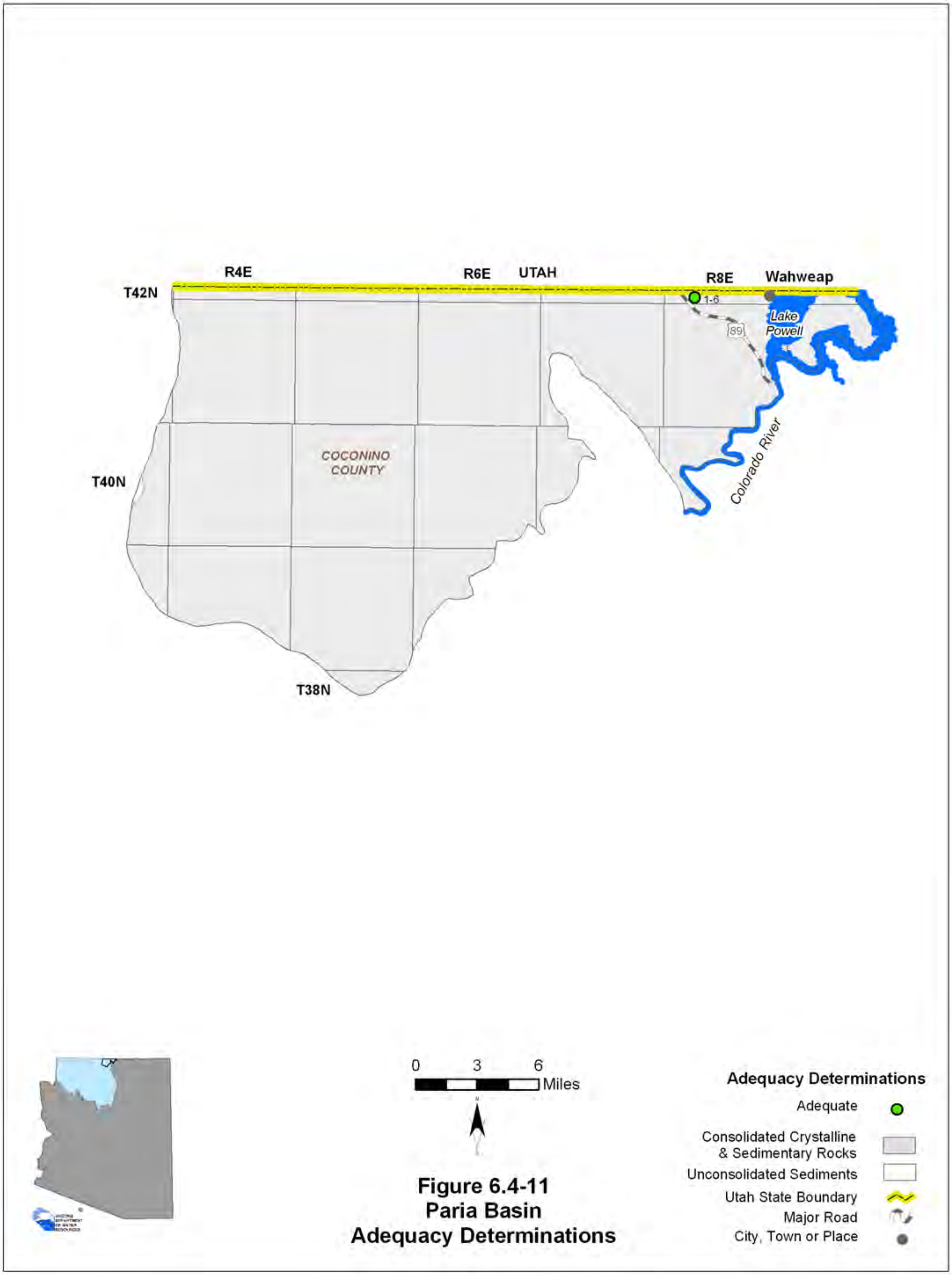


Figure 6.4-11
Paria Basin
Adequacy Determinations

Paria Basin
References and Supplemental Reading

References

A

Arizona Corporation Commission (ACC), 2005, Annual reports, Private Sewer companies, 1990 to 2005: ACC Utilities Division.*

______, 2005, Annual reports, Small water providers, 1990 to 2005: ACC Utilities Division.

Arizona Crop and Livestock Reporting Service, 1973, 1972 Arizona Agricultural Statistics: Bulletin S-8.

Arizona Department of Economic Security (DES), 2005, Workforce Informer: Data file, accessed August 2005, http://www.workforce.az.gov.*

Arizona Department of Environmental Quality, 2005, Active dairy farms & feedlots: Data file, received October 2005.

______, 2005, ADEQSWI: Data file, received September 2005.

______, 2005, ADEQWATP: Data file, received May 2005.

______, 2005, ADEQWWTP: Data file, received August 2005.

______, 2005, Azurite: Data file, received September 2005.

______, 2005, Effluent dependent waters: GIS cover, received December 2005.

______, 2005, Impaired lakes and reaches: GIS cover, received January 2006.*

______, 2005, Surface water sources used by water providers: Data file, received June 2005.

______, 2005, WWTP and permit files: Miscellaneous working files, received July 2005.

______, 2004, Water providers with arsenic concentrations in wells over 10ppb: Data file, received August 2004.

______, 2004, Water quality exceedences by watershed: Data file, received June 2004.

______, 2004, Water quality exceedences for drinking water providers in Arizona: Data file, received September 2004.*

Arizona Department of Mines and Mineral Resources (ADMMR), 2005, Active mines in Arizona: Database, accessed at http:// www.admmr.state.az.us.

Arizona Department of Water Resources (ADWR), 2006, Assured and adequate water supply applications: Project files, ADWR Hydrology Division.*

______, 2005, Agricultural Surface Water Use Estimates: Unpublished analysis, ADWR Office of Resource Assessment Planning.*

______, 2005, Automated recorder sites: Data files, ADWR Basic Data Unit.*

______, 2005, 2004 rural water provider questionnaire: Data files, ADWR Office of Resource Assessment Planning.

______, 2005, Assured and adequate water supply determinations: Database, ADWR Office of Assured and Adequate Water Supply.*

_______, 2005, Flood warning gages: Database, ADWR Office of Water Engineering.

_______, 2005, Inspected dams: Database, ADWR Office of Dam Safety.

_______, 2005, Non-jurisdictional dams: Database, ADWR Office of Dam Safety.

_______, 2005, Groundwater Site Inventory (GWSI): Database, ADWR Hydrology Division.*

______, 2005, Registry of surface water rights: ADWR Office of Water Management.*

_____, 2005, Water Protection Fund: Database, ADWR Office of Drought, Conservation and Riparian Planning.
_____, 2005, Water use by golf courses in rural Arizona: Unpublished analysis, ADWR Office of Regional Strategic Planning.
_____, 2005, Wells55: Database.*
_____, 2002, Groundwater quality exceedences in rural Arizona from 1975 to 2001: Data file, ADWR Office of Regional Strategic Planning.*
_____, 1994, Arizona Water Resources Assessment, Vol. I, Inventory and Analysis.*
_____, 1994, Arizona Water Resources Assessment, Vol. II, Hydrologic Summary.*
_____, 1990, Draft outline of basin profiles for the state water assessment: ADWR Statewide Planning Division, Memorandum to L. Linser, D.W., January, 16, 1990.*
Arizona Game and Fish Department (AGF), 2005, Arizona Waterways: Data file, received April 2005.
_____, 1997 & 1993, Statewide riparian inventory and mapping project: GIS cover.*
_____, 1982, Arizona Lakes Classification Study.
Arizona Land Resource Information System (ALRIS), 2005, Springs: GIS cover, accessed January 2006 at http://www.land.state.az.us/alris/index.html.*
_______, 2005, Streams: GIS cover, accessed 2005 at http://www.land.state.az.us/ alris/index.html.*
_____, 2005, Water features: GIS cover, accessed July 2005 at http://www.land.state.az. us/alris/index.html.*
_____, 2004, Land ownership: GIS cover, accessed in 2004 at http://www.land.state.az.us/alris/index.html.*
Arizona Meteorological Network (AZMET), 2005, Arizona climate stations: Pan evaporation data, accessed December 2005 at http://www.ag.arizona. edu/azmet/locate.html.
Arizona Water Commission, 1975, Summary, Phase I, Arizona State Water Plan, Inventory of resource and uses.

D

Diroll, M., and Marsh, D., 2006, Status of water quality in Arizona-2004 integrated 305(b) assessment and 303(d) listing report: ADEQ report.*

E

Environmental Protection Agency (EPA), 2005, Surf Your Watershed: Facility reports, accessed April 2005 at http://oaspub.epa.gov/enviro/ef_home2.water.
_____, 2005, 2000 and 1996, Clean Watershed Needs Survey: datasets, accessed March 2005 at http://www.epa.gov/owm/mtb/cwns/index.htm.

F

Fisk, G.G., Duet, D.W., Evans, C.E., Angernoth, N.K., and Longsworth, S.A., 2004, Water Resources Data, Arizona Water Year 2003: USGS Water-Data Report AZ-03-1.*

K

Konieczki, A.D. and Wilson, R.P., 1992, Annual summary of ground-water conditions in Arizona, spring 1986 to spring 1987: USGS Open File Report 92-54.*

M

McCormack, H.F., Fisk, G.G., Duet, N.R., Evans, D.W., Roberts, W.P., and Castillo, N.K., 2002, Water resources data Arizona, water year 2002: USGS Water Data Report AZ-02-1.*

N

Natural Resources Conservation Service (NRCS), 2005, SNOTEL (Snowpack Telemetry) stations: Data file, accessed December 2005 at http://www3.wcc.nrcs.usda. gov/nwcc/sntlsites.jsp?state=AZ.

_____, 2005, Snow Course stations: Data file, accessed December 2005 at http://www.wcc.nrcs.usda.gov/nwcc/snow-course-sites.jsp?state=AZ

O

Oregon State University, Spatial Climate Analysis Service (SCAS), 2006, Average annual precipitation in Arizona for 1961-1990: PRISM GIS cover, accessed in 2006 at www.ocs.orst.edu/prism.*

P

Pope, G.L., Rigas, P.D., and Smith, C.F., 1998, Statistical summaries of streamflow data and characteristics of drainage basins for selected streamflow-gaging stations in Arizona through water year 1996: USGS Water Resources Investigations Report 98-4225.*

Price, D., and Arnow, T., 1974, Summary appraisals of the nation's groundwater resources, upper Colorado region: USGS Professional Paper 813-C.*

T

Tadayon, S., 2004, Water withdrawals for irrigation, municipal, mining, thermoelectric-power, and drainage uses in Arizona outside of the active management areas, 1991-2000: USGS Scientific Investigations Report 2004-5293, 27 pp.*

U

US Army Corps of Engineers, 2004 and 2005, National Inventory of Dams: Arizona Dataset, accessed November 2004 to April 2005 at http://crunch.tec.army.mil /nid/webpages/nid.cfm. *

US Geological Survey (USGS), 2006, Average annual runoff in the United States, 1951-1980: Data file, accessed March 2006 at http://aa179.cr.usgs.gov/metadata/ wrdmeta/runoff.htm.*

_____, 2006, Springs and spring discharges: Dataset, received November 2004 and January 2006 from USGS office in Tucson, AZ.*

_____, National Hydrography Dataset: Arizona dataset, accessed at http://nhd.usgs.gov/.*

_____, 2005, National Water Information System (NWIS): Arizona dataset, accessed December 2005 at http://waterdata.usgs.gov/nwis.*

_____, 2004, Southwest Regional Gap analysis study- land cover descriptions: Electronic file, accessed January 2005 at http://earth.gis.usu.edu/swgap.*

_____, 1981, Geographic digital data for 1:500,000 scale maps: USGS National Mapping Program Data Users Guide.*

V

Valencia, R.A., Wennerlund, J.A., Winstead, R.A., Woods, S., Riley, L., Swanson, E., and Olson, S., 1993, Arizona riparian inventory and mapping project: Arizona Game and Fish Department.

W

Wahl, C.R., Boe, S.R., Wennerlund, R.A., Winstead, R.A., Allison, L.J., Kubly, D.M., 1997, Remote sensing mapping of Arizona intermittent stream riparian areas: Arizona Game and Fish Technical Report 112.

Water Infrastructure Finance Authority of Arizona (WIFA), 2005, Clean Watershed Needs Survey-2004: Unpublished data sheets, received July 2005.

Western Regional Climate Center (WRCC), 2005, Pan evaporation stations: Data file accessed December 2005 at http://www4.ncdc.noaa.gov/cgi-win/wwcgi.dll?wwDI~GetCity~USA.*

______, 2005, Precipitation and temperature stations: Data file, accessed December 2005 at http://www4.ncdc.noaa.gov/cgi-win/wwcgi.dll?wwDI~GetCity~USA.*

Wilson, R.P., 1992, Summary of groundwater conditions in Arizona 1985 to 1986: USGS Water Resources Investigation Report, 90-4179.*

*All references marked with an asterisk contain information that was directly used in the basin summaries, tables or maps.

Supplemental Reading

Andersen, Mark, 2005, Assessment of water availability in the Lower Colorado River basin: in Conservation and Innovation in Water Management: Proceedings of the 18th annual Arizona Hydrological Society Symposium, Flagstaff, Arizona, September, 2005.

Berghoff, K., Boobar, L., and Ritenour, J., 1998, The effects of land use on water quality at the beaches of Lake Powell: in Water at the Confluence of Science, Law and Public Policy: Proceedings from the 11th annual Arizona Hydrological Society Symposium, September 1998, Tucson, Arizona, p.11.

Bureau of Land Management, 2005, Draft resource management plan and draft Environmental Impact Statement for Vermilion Cliffs National Monument, and the Grand Canyon Parashant National Monument: BLM Arizona Field Office and NPS joint report, 2005.

Bureau of Reclamation, 2006, North Central Arizona Water Supply Study: Report.

Enzel, Y., Ely, L.L., House, P.K., Baker, V.R., and Webb, R.H., 1993, Paleoflood evidence for a natural upper bound to flood magnitudes in the Colorado River Basin: Water Resources Research, vol. 29, no. 7, p. 2287-2297.

Flynn, M., Hornewer, N., 2003, Variations in sand storage measured at monumented cross sections in the Colorado River between Glen Canyon and Lava Falls Rapid, Northern Arizona, 1992-1999:USGS Water Resources Investigations Report 03-4104, 39 p.

Gauger, R.W., 1997, River-stage data Colorado River, Glen Canyon Dam to upper Lake Mead, Arizona, 1990-1994: USGS Open–File Report 96-626, 20 p.

Hart, H.E., and others, 2004, Physical and chemical characteristics of Knowles, Forgotten, and Moqui canyons and the effects of recreational use on water quality, Lake Powell, Arizona and Utah: USGS Scientific Investigations Report 2004-5120, 40 p.

Hart, R.J., 1999, Water Quality of the Colorado River monitored by the USGS National Stream Quality Accounting Network: in Water Issues and Partnerships for Rural Arizona: Proceedings of the 12th annual symposium of the Arizona Hydrological Society, September 1999, Hon Dah, Arizona.

Hart, R.J. and Sherman, K.M., 1996, Physical and chemical characteristics of Lake Powell at the forebay and outflows of Glen Canyon Dam, northeastern Arizona: USGS Water Resources Investigations Report 96-4016, 78 p.

Hereford, R., Webb, G., and Graham, S., 2002, Precipitation history of the Colorado Plateau region, 1990 – 2000: USGS Fact sheet 119-02.

Mondry, Z., 2002, Drought, storms, and stream flow and temperature observations from the Coconino and Prescott National Forests: in Sustainability Issues of Arizona's Regional Watersheds: Proceedings from the 15th annual Arizona Hydrological Society Symposium, September 2003, Mesa, Arizona.

Mullen, G., Springer, A., Kolb, T., and Ament, A., 2002, Restoration of wet meadows: Influence of burning herbaceous communities on groundwater recharge: in Water Transfers: Past, Present and Future: Proceedings of the 15th annual symposium of the Arizona Hydrological Society, September 2002, Flagstaff, Arizona.

Rocky Mountain Institute, 2002, North central Arizona water demand study: Phase 1, draft report.

Rote, J.J., Flynn, M.E., and Bills, D.J., 1997, Hydrologic data, Colorado River and major tributaries, Glen Canyon Dam to Diamond Creek, Arizona, water years 1990 -1995: USGS Open–File Report 97-250, 474 p.

Smith J.D., and Wiele, S., 1991, Flow and sediment transport in the Colorado River between Lake Powell and Lake Mead: USGS report 38 p.

Topping, D.J., Schmidt, J.C., Vierra, L.E., Computation and analysis of the instantaneous-discharge record for the Colorado River at Lees Ferry, Arizona, May 8, 1921, through

September 30, 2000: USGS Professional Paper 1677.

Ward, J., 2002, Groundwater on the Plateau: Southwest Hydrology, Vol.1, No. 4.

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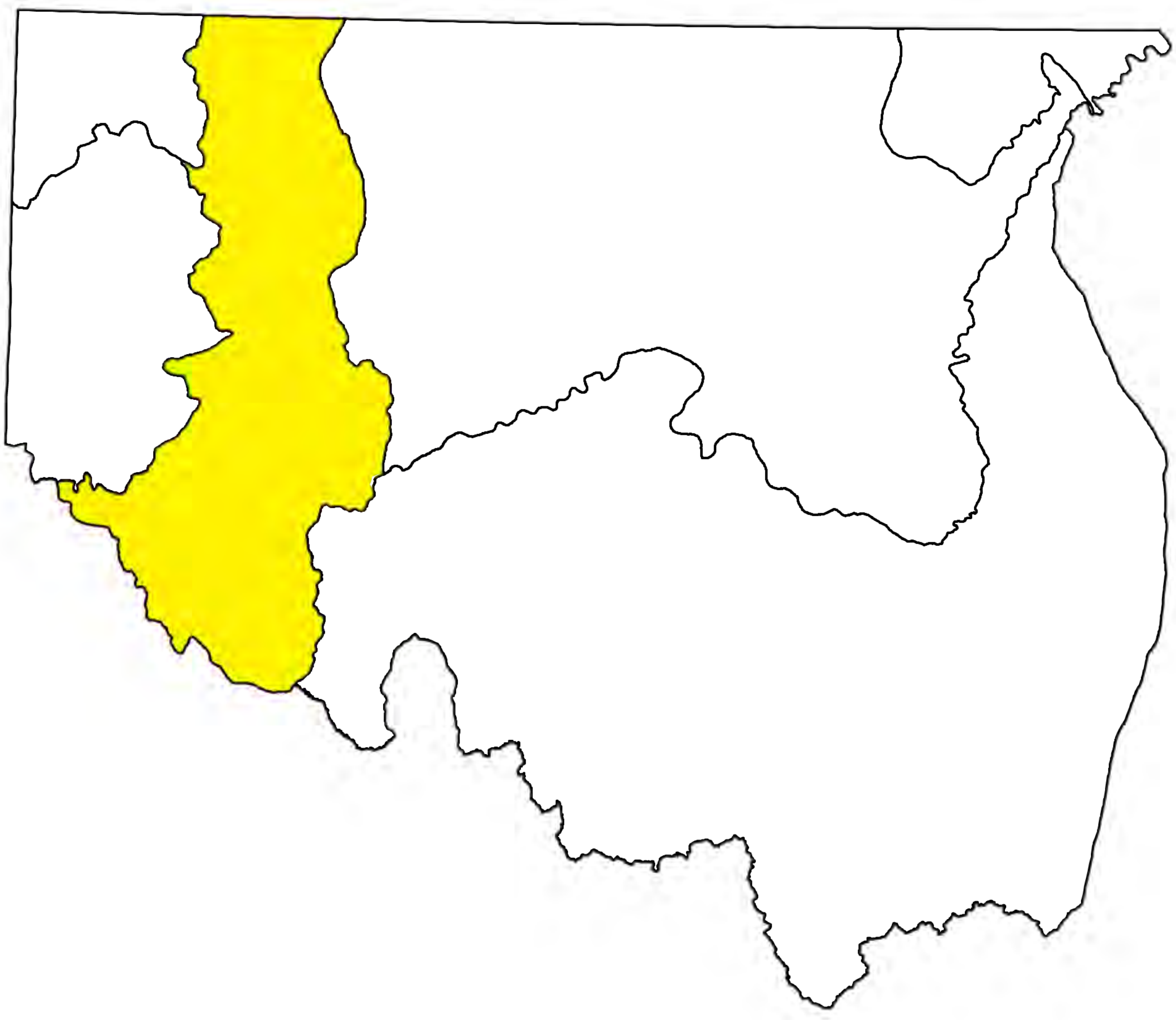
Section 6.5
Shivwits Plateau Basin



6.5.1 Geography of the Shivwits Plateau Basin

The Shivwits Plateau Basin, located in the central part of the planning area is 1,821 square miles in area. Geographic features and principal communities are shown on Figure 6.5-1. The basin is characterized by plateaus, canyons and cliffs. Vegetation is primarily Great Basin conifer woodland, Great Basin and Mohave desertscrub and plains grassland with small areas of Rocky Mountain montane forest and interior chaparral. (See Figure 6.0-9)

- Principal geographic features shown on Figure 6.5-1 are:
    - Basin places of Wolf Hole, Mount Trumbull and Oak Grove
    - The Colorado River and the Lower Granite Gorge of the Grand Canyon forming the southern basin boundary
    - Shivwits Plateau running north south throughout most of the basin and the Sanup Plateau in the southwest
    - Hurricane Cliffs on the eastern basin boundary
    - Mt. Dellenbaugh, located south of Oak Grove, the highest point in the basin at 7,072 feet

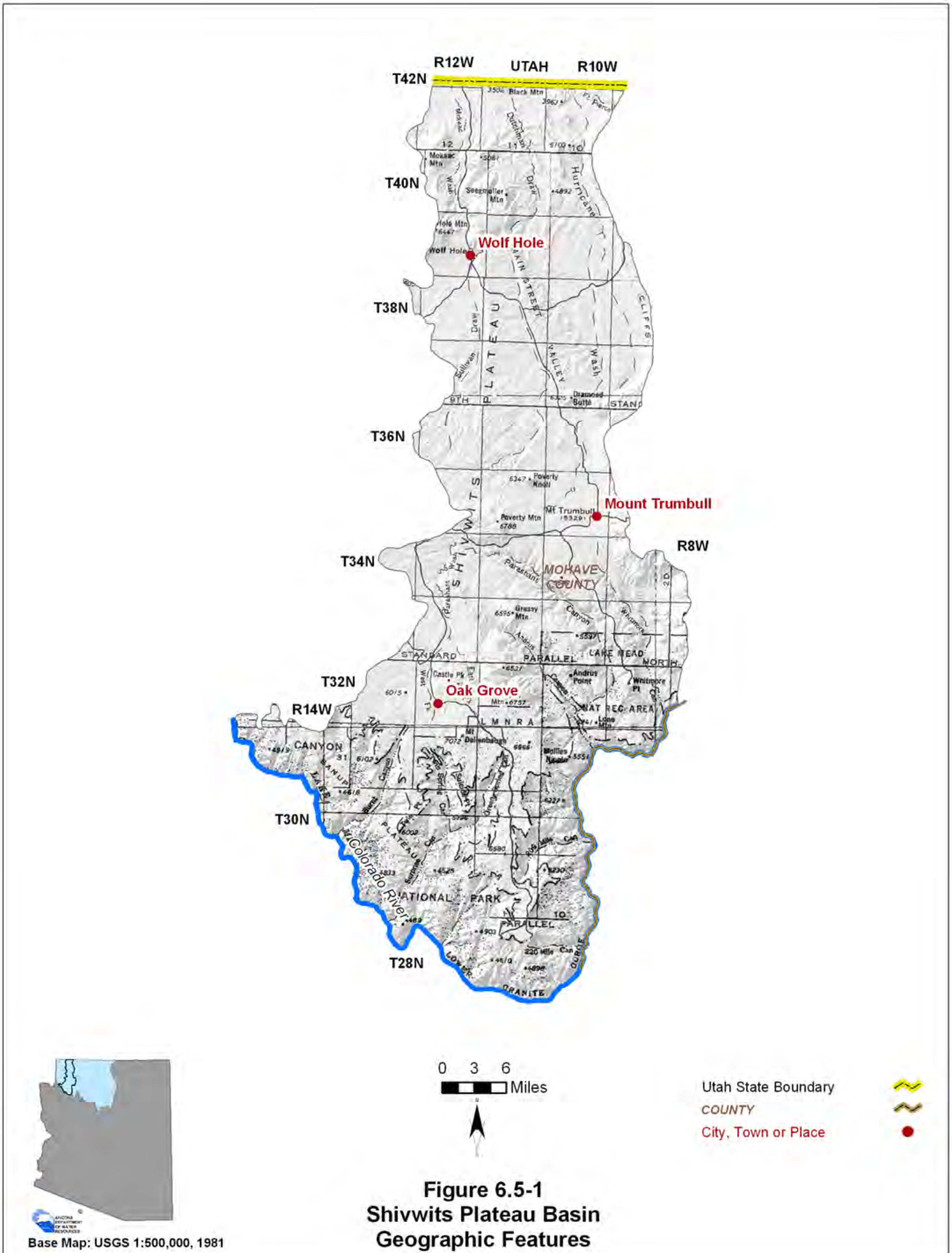


Figure 6.5-1
Shivwits Plateau Basin
Geographic Features

6.5.2 Land Ownership in the Shivwits Plateau Basin

Land ownership, including the percentage of ownership by category, for the Shivwits Plateau Basin is shown in Figure 6.5-2. Principal features of land ownership in this basin are the large parcels of land managed by the U.S. Bureau of Land Management (BLM) and National Park Service (NPS). Thirty-four percent of the basin is managed jointly by the BLM and NPS as the Grand Canyon-Parashant National Monument. A description of land ownership data sources and methods is found in Volume 1, Section 1.3.8. Land ownership categories are discussed below in the order of percentage from largest to smallest in the basin.

U.S. Bureau of Land Management (BLM)

- 53.7% of the land is federally owned and managed by the Arizona Strip Field Office of the Bureau of Land Management.
- BLM land in the basin includes a portion of the Grand Canyon-Parashant National Monument and the 14,650 acre Mt. Logan Wilderness, located south of Mount Trumbull.
- Land use includes grazing, recreation and resource conservation.

National Park Service (NPS)

- 38.1% of the land is federally owned and managed by the National Park Service as the Grand Canyon National Park and the Grand Canyon-Parashant National Monument.
- Land use includes resource conservation and recreation.

State Trust Land

- 4.9% of the land is held in trust for the public schools under the State Trust Land system.
- State land is located throughout most of the basin and is interspersed with BLM and private lands.
- Primary land use is grazing.

Private

- 3.3% of the land is private.
- The majority of the private land is in the vicinity of Mt. Trumbull and north of Oak Grove.
- Land uses include domestic and ranching.

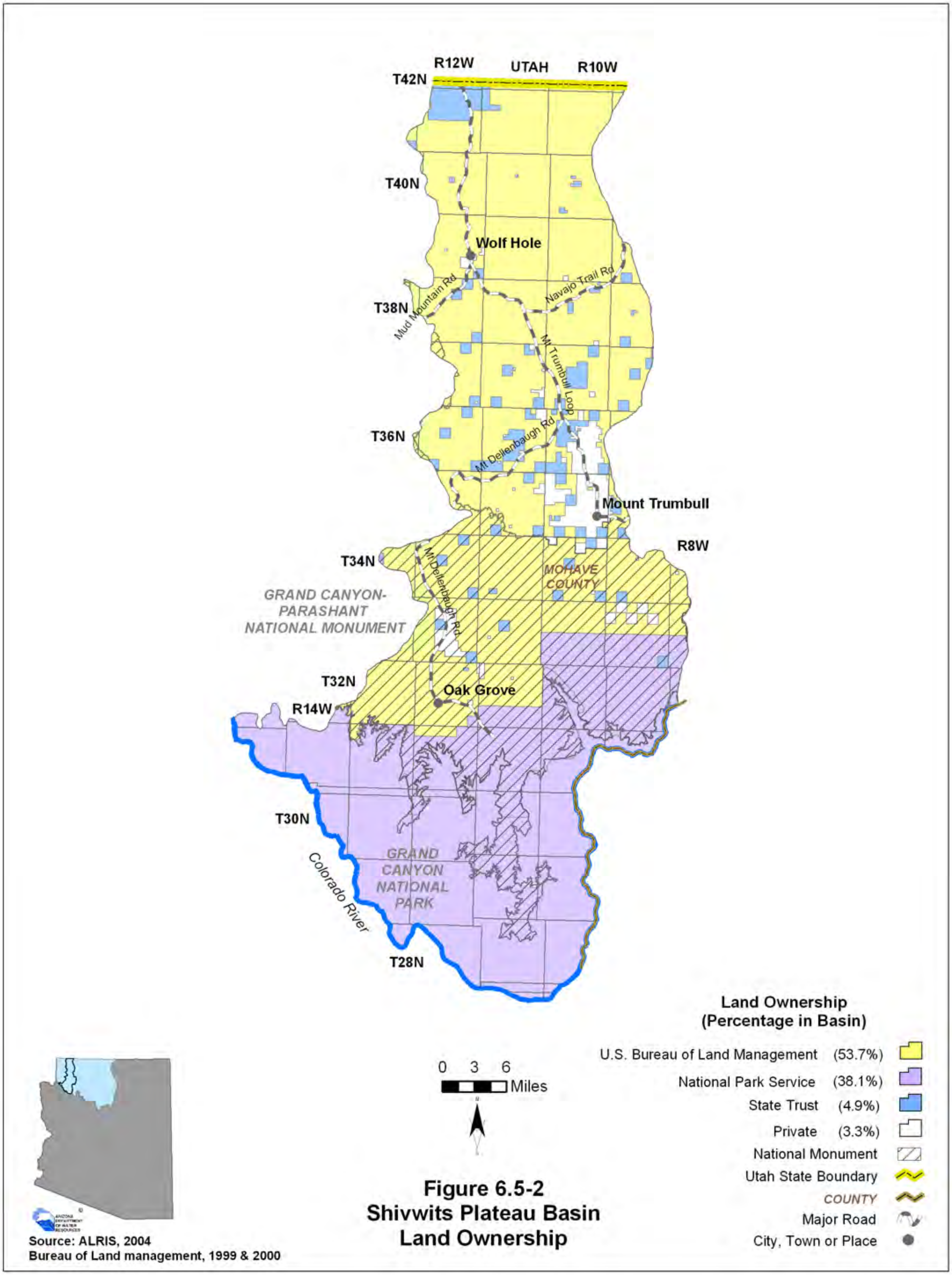


Figure 6.5-2
Shivwits Plateau Basin
Land Ownership

6.5.3 Climate of the Shivwits Plateau Basin

The Shivwits Plateau Basin does not contain NOAA/NWS, Evaporation Pan, AZMET or SNOTEL/Snowcourse stations. Figure 6.5-3 shows precipitation contour data from the Spatial Climate Analysis Service (SCAS) at Oregon State University. A description of the climate data sources and methods is found in Volume 1, Section 1.3.3.

SCAS Precipitation Data

- See Figure 6.5-3
- Average annual rainfall is as high as 20 inches along the central eastern basin boundary and as low as four inches at the Colorado River on the basin's western boundary.

Table 6.5-1 Climate Data for the Shivwits Plateau Basin

A. NOAA/NWS Co-op Network:

Station Name	Elevation (in feet)	Period of Record Used for Averages	Average Temperature Range (in F)		Average Precipitation (in inches)				
			Max/Month	Min/Month	Winter	Spring	Summer	Fall	Annual
None									

Source: WRCC, 2003

B. Evaporation Pan:

Station Name	Elevation (in feet)	Period of Record Used for Averages	Avg. Annual Evap (in inches)
None			

Source: WRCC, 2003.

C. AZMET:

Station Name	Elevation (in feet)	Period of Record Used for Averages	Average Annual Reference Evaportranspiration, in inches (*Number of years to calculate averages*)
None			

Source: Arizona Meteorological Network, 2005

D. SNOTEL/Snowcourse:

Station Name	Elevation (in feet)	Period of Record Used for Averages	Average Snowpack, at Beginning of the Month, as Inches Snow Water Content *(Number of measurements to calculate average)*					
			Jan.	Feb.	March	April	May	June
None								

Source: NRCS, 2005

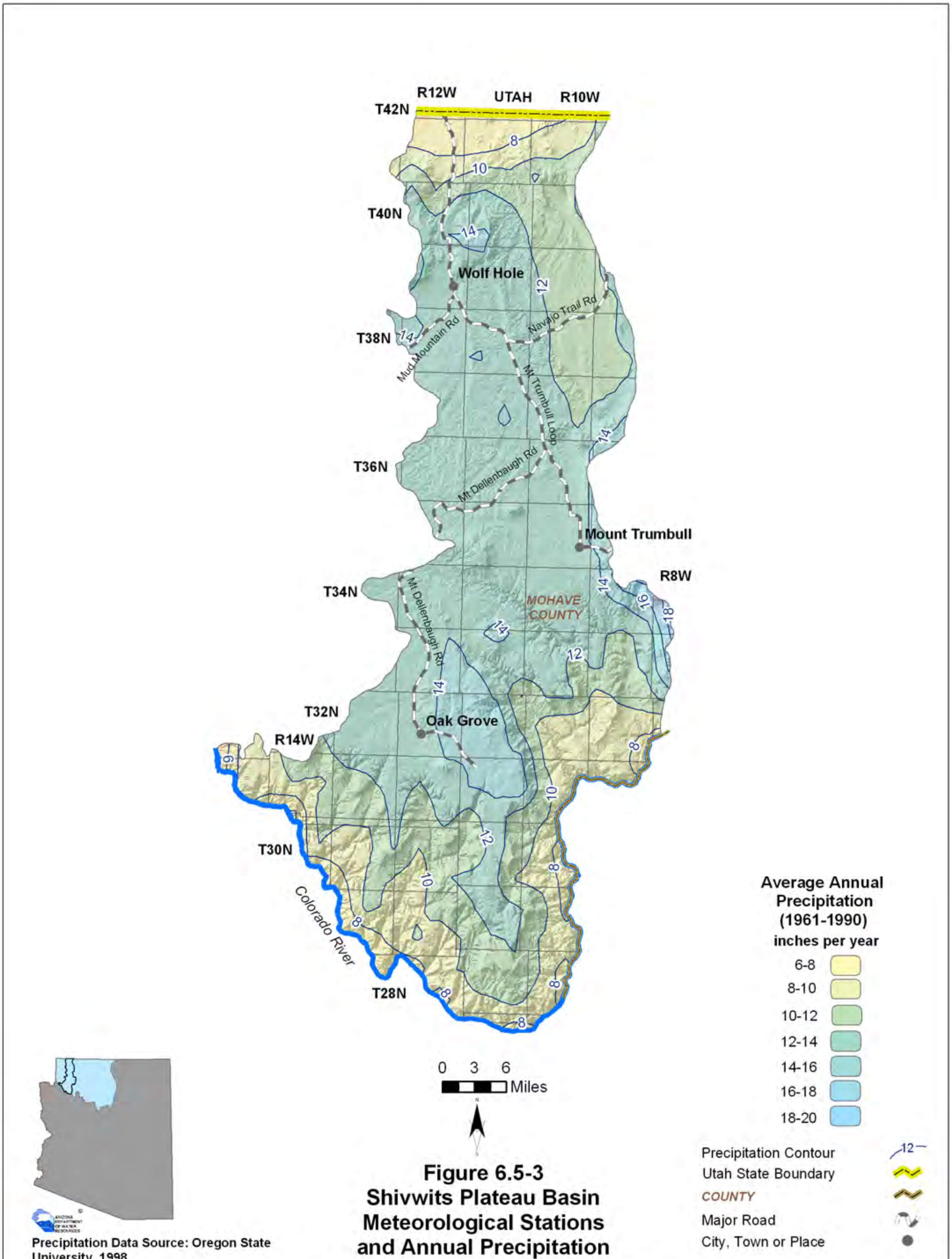


Figure 6.5-3
Shivwits Plateau Basin Meteorological Stations and Annual Precipitation

6.5.4 Surface Water Conditions in the Shivwits Plateau Basin

There are no streamflow data or flood ALERT equipment in this basin. Reservoir and stockpond data, including maximum storage or maximum surface area, are shown in Table 6.5-4. The USGS runoff contours and large reservoirs are shown on Figure 6.5-4. A description of stream data sources and methods is found in Volume 1, Section 1.3.16. A description of reservoir data sources and methods is found in Volume 1, Section 1.3.11. A description of stockpond data sources and methods is found in Volume 1, Section 1.3.15.

Reservoirs and Stockponds

- Refer to Table 6.5-4.
- The only large reservoir in the basin is Wolf Hole with a maximum surface area of 58 acres. This reservoir is used for fire protection or as a stock or farm pond.
- Surface water is stored or could be stored in two small reservoirs.
- There are 369 registered stockponds in this basin.

Runoff Contour

- Refer to Figure 6.5-4.
- Average annual runoff is highest, 0.5 inches per year or 26 acre-feet per square mile, in the northwestern portion of the basin near Mud Mountain Road and decreases to 0.1 inches, or five acre-feet per square mile, in the southernmost and central portions of the basin.

Table 6.5-2 Streamflow Data for the Shivwits Plateau Basin

Station Number	USGS Station Name	Drainage Area (in mi^2)	Mean Basin Elevation (in feet)	Period of Record	Average Seasonal Flow (% of annual flow)				Annual Flow/Year (in acre-feet)				Years of Record
					Winter	Spring	Summer	Fall	Minimum	Median	Mean	Maximum	
None													

Sources: USGS NWIS, USGS 1998 and USGS 2003.

Table 6.5-3 Flood ALERT Equipment in the Shivwits Plateau Basin

Station ID	Station Name	Station Type	Install Date	Responsibility
None				

Table 6.5-4 Reservoirs and Stockponds in the Shivwits Plateau Basin

A. Large Reservoirs (500 acre-feet capacity and greater)

MAP KEY	RESERVOIR/LAKE NAME *(Name of dam, if different)*	OWNER/OPERATOR	MAXIMUM STORAGE (AF)	USE	JURISDICTION
None Identified by ADWR at this time					

B. Other Large Reservoirs (50 acre surface area or greater)[1]

MAP KEY	RESERVOIR/LAKE NAME *(Name of dam, if different)*	OWNER/OPERATOR	MAXIMUM SURFACE AREA (acres)	USE[2]	JURISDICTION
1	Wolf Hole	Private	58	P	NA

C. Small Reservoirs (greater than 15 acre-feet and less than 500 acre-feet capacity)

Total number: 1
Total maximum storage: 20 acre-feet

D. Other Small Reservoirs (between 5 and 50 acres surface area)[1]

Total number: 1
Total surface area: 10 acres

E. Stockponds (up to 15 acre-feet capacity)

Total number: 369

[1] Capacity data not available to ADWR
[2] P=fire protection, stock or farm pond

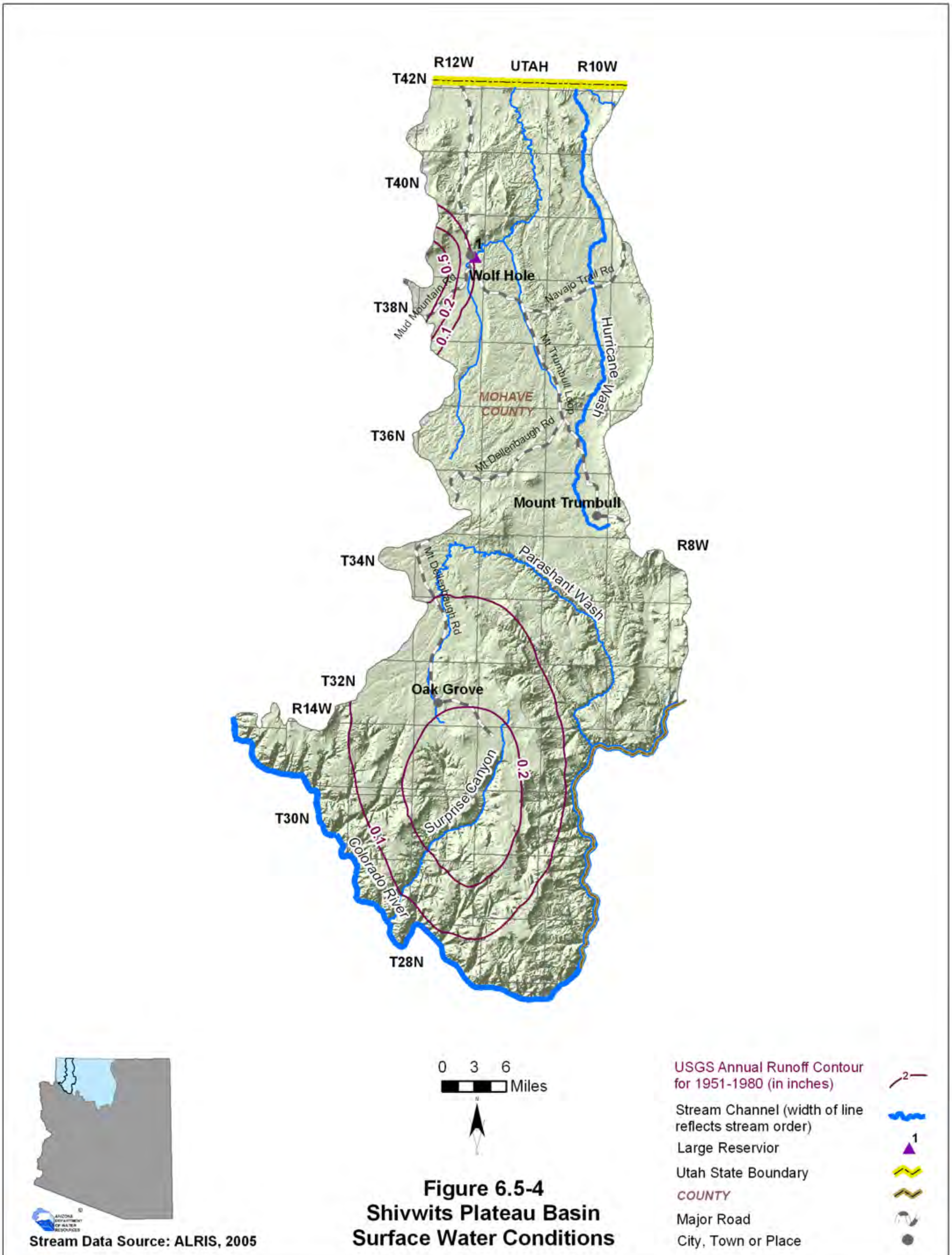


Figure 6.5-4
Shivwits Plateau Basin
Surface Water Conditions

6.5.5 Perennial/Intermittent Streams and Major Springs in the Shivwits Plateau Basin

Major springs with discharge rates and date of measurement and the total number of springs in the basin are shown in Table 6.5-5. The locations a major spring and perennial stream are shown on Figure 6.5-5. A description of data sources and methods for intermittent and perennial reaches is found in Volume 1, Section 1.3.16. A description of spring data sources and methods is found in Volume 1, Section 1.3.14.

- There are no intermittent streams and the only perennial stream is the Colorado River.
- There is one major spring in the basin, Spring Canyon located at the Colorado River, with a discharge rate of 331 gallons per minute (gpm).
- Springs with measured discharge of 1 to 10 gpm are not mapped but coordinates are given in Table 6.5-5B. There are five minor springs in this basin.
- The total number of springs, regardless of discharge, identified by the USGS varies from 51 to 56, depending on the database reference.

Table 6.5-5 Springs in the Shivwits Plateau Basin

A. Major Springs (10 gpm or greater):

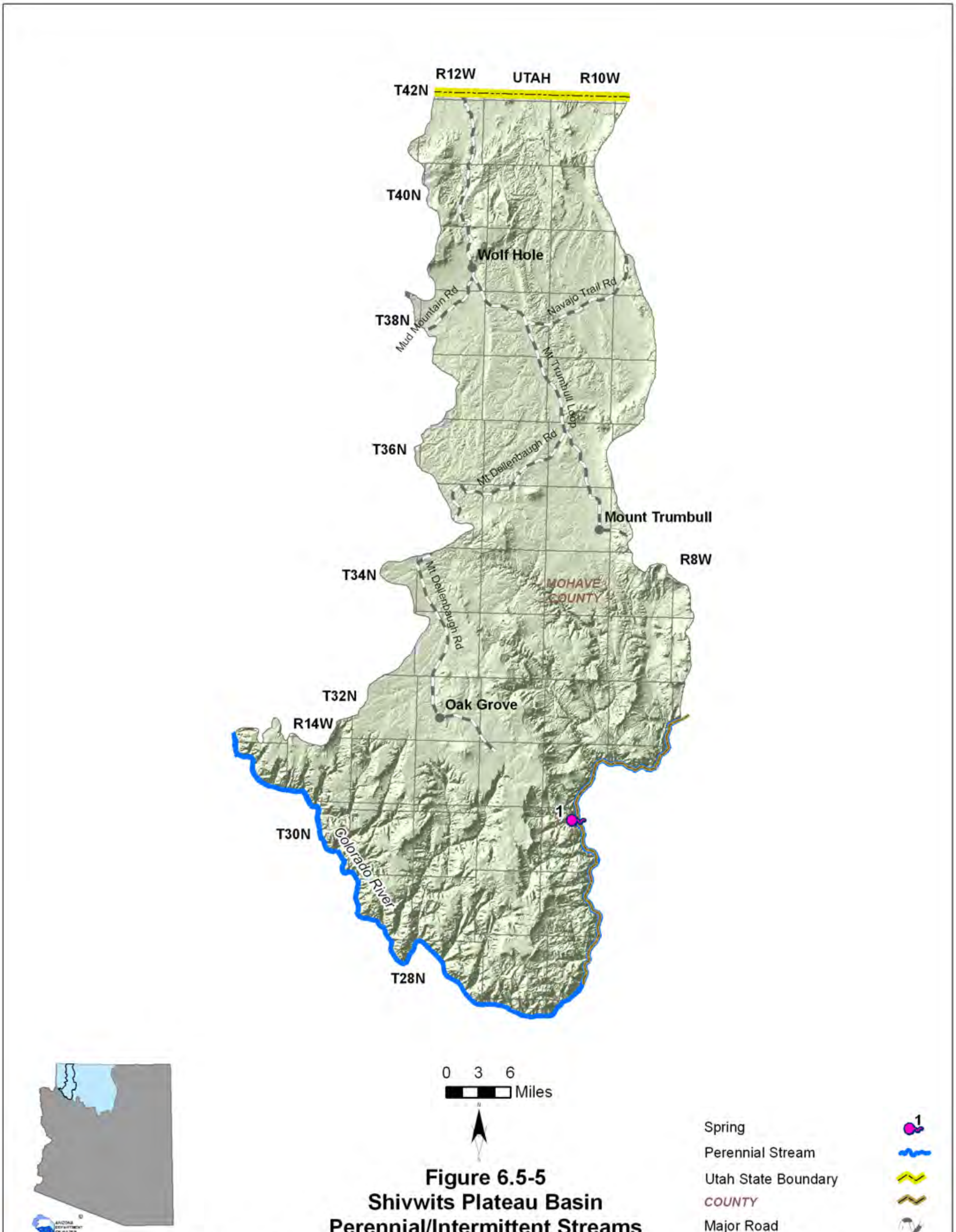
Map Key	Name	Location		Discharge (in gpm)[1]	Date Discharge Measured
		Latitude	Longitude		
1	Spring Canyon[2]	360107	1132106	331	3/20/2004

B. Minor Springs (1 to 10 gpm):

Name	Location		Discharge (in gpm)[1]	Date Discharge Measured
	Latitude	Longitude		
Ivanpatch	362340	1132823	3	7/20/1951
Big	362014	1131125	2	8/10/1976
Green	360538	1132825	1	6/18/2000
Poverty	362355	1133251	1	9/8/1976
Russell	363120	1131930	1	7/21/1951

C. Total number of springs, regardless of discharge, identified by USGS (see ALRIS, 2005 and NHD, 2006): 51 to 56

Notes:
[1] Most recent measurement identified by ADWR
[2] Spring is not displayed on current USGS topo maps



Stream Data Source: AGFD, 1993 & 1997

Figure 6.5-5
Shivwits Plateau Basin
Perennial/Intermittent Streams
and Major (>10 gpm) Springs

6.5.6 Groundwater Conditions of the Shivwits Plateau Basin

Major aquifers, well yields, number of index wells and date of last water-level sweep are shown in Table 6.5-6. Figure 6.5-6 shows water-level change between 1990-1991 and 2003-2004. Figure 6.5-7 contains hydrographs for selected wells shown on Figure 6.5-6. A description of aquifer data sources and methods is found in Volume 1, Section 1.3.2. A description of well data sources and methods, including water-level changes and well yields, is found in Volume 1, Section 1.3.19.

Major Aquifers

- Refer to Table 6.5-6 and Figure 6.5-6.
- The major aquifer in the basin is the recent stream alluvium.
- Almost all of the basin geology consists of consolidated crystalline and sedimentary rock.
- Data on groundwater flow direction is not available for this basin.

Well Yields

- Refer to Table 6.5-6
- One source of well yield information, based on 17 reported wells, indicates that the median well yield in this basin is five gallons per minute.

Water Level

- Refer to Figure 6.5-6. Water levels are shown for wells measured in 2003-2004.
- There are no index wells in this basin.
- Water level information is available for one well in this basin, with a depth to water of 960 feet.
- A hydrograph corresponding to the well shown on Figure 6.5-6 is shown in Figure 6.5-7.

Table 6.5-6 Groundwater Data for the Shivwits Plateau Basin

Basin Area, in square miles:	1,821	
	Name and/or Geologic Units	
Major Aquifer(s):	Recent Stream Alluvium	
Well Yields, in gpm:	N/A	Measured by ADWR and/or USGS
	Range 2-35 Median 5 (17 wells reported)	Reported on registration forms for all wells
	Range 0-45	ADWR (1990 and 1994)
	Range 0-10	USGS (1994)
Estimated Natural Recharge, in acre-feet/year:	N/A	
Estimated Water Currently in Storage, in acre-feet:	N/A	ADWR (1990 and/or 1994)
	N/A	Arizona Water Commission (1975)
Current Number of Index Wells:	0	
Date of Last Water-level Sweep:	1976 (9 wells measured)	

N/A=Not Available

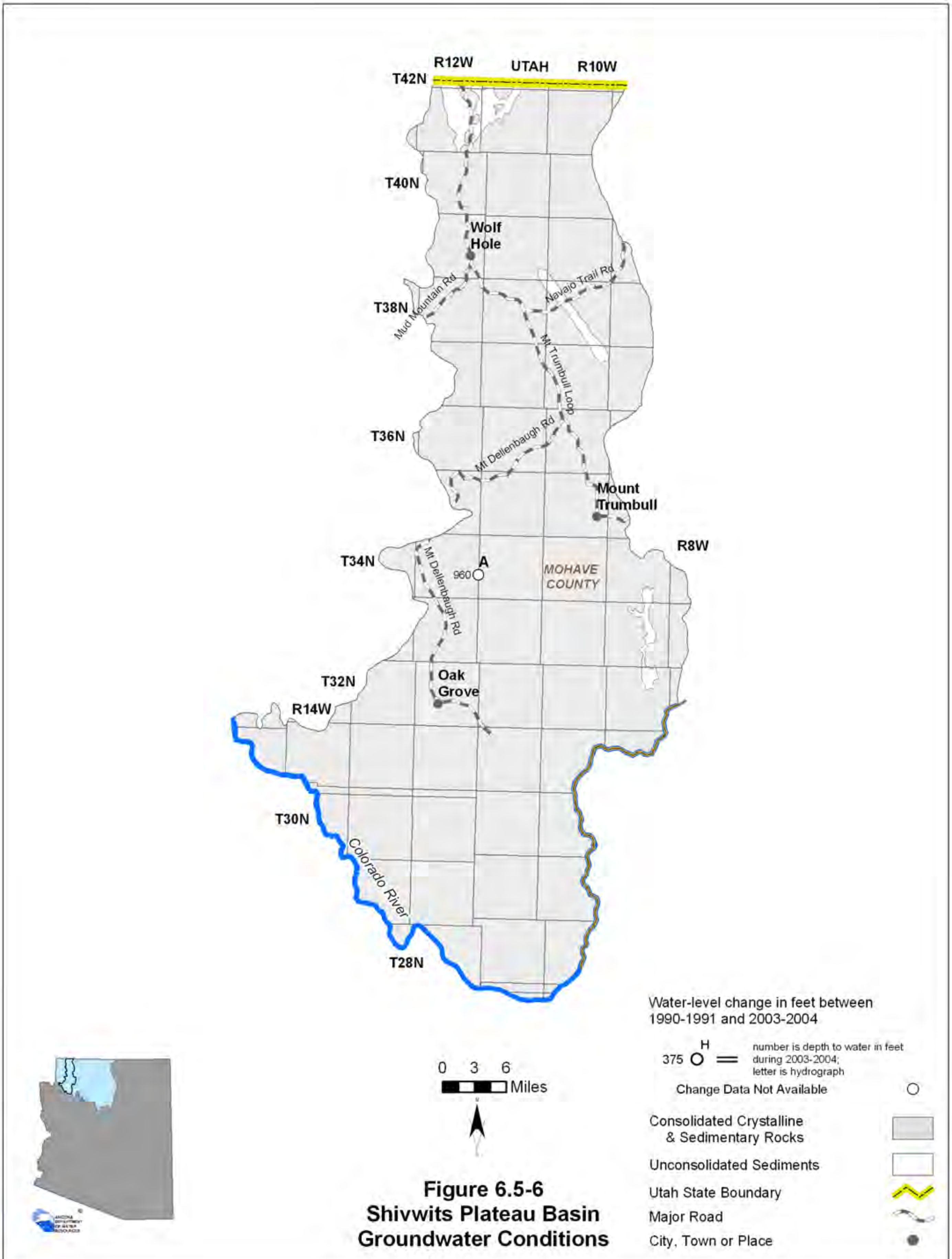
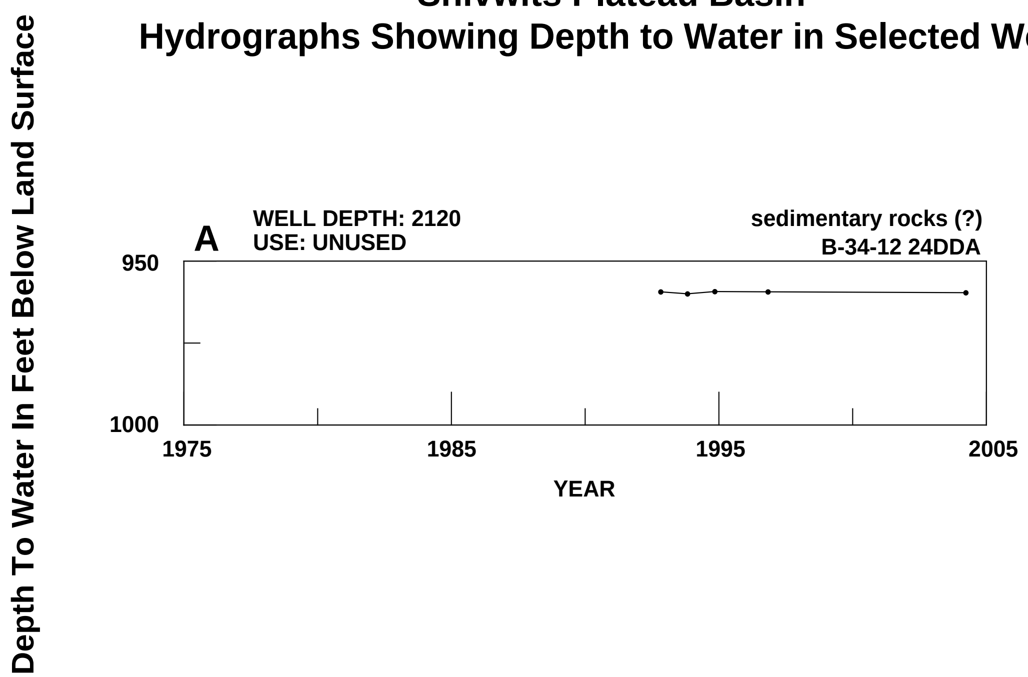


Figure 6.5-6
Shivwits Plateau Basin
Groundwater Conditions

Figure 6.5-7
Shivwits Plateau Basin
Hydrographs Showing Depth to Water in Selected Wells



6.5.7 Water Quality of the Shivwits Plateau Basin

Wells, springs and mine sites with parameter concentrations that have equaled or exceeded drinking water standard(s), including location and parameter(s) are shown in Table 6.5-7A. Impaired lakes and streams with site type, name, length of impaired reach, area of impaired lake, designated use standard and parameter(s) exceeded is shown in Table 6.5-7B. Figure 6.5-8 shows the location of water quality occurrences keyed to Table 6.5-7. A description of water quality data sources and methods is found in Volume 1, Section 1.3.18. Not all parameters were measured at all sites; selective sampling for particular constituents is common.

Wells, Springs and Mines

- Refer to Table 6.5-7A.
- One spring has a parameter concentration that has equaled or exceeded the drinking water standard for arsenic.

Lakes and Streams

- Refer to Table 6.5-7B.
- The water quality standard for suspended sediment concentration was exceeded in one 28-mile stream reach, the Colorado River from Parashant Canyon to Diamond Creek. This impaired reach also forms part of the border with the Coconino Plateau Basin.
- This reach is not part of the ADEQ water quality improvement effort called the Total Maximum Daily Load (TMDL) Program at this time.

Table 6.5-7 Water Quality Exceedences in the Shivwits Plateau Basin[1]

A. Wells, Springs and Mines

Map Key	Site Type	Site Location			Parameter(s) Concentration has Equaled or Exceeded Drinking Water Standard (DWS)[2]
		Township	Range	Section	
1	Spring	30 North	13 West	24	As

B. Lakes and Streams

Map Key	Site Type	Site Name	Length of Impaired Stream Reach (in miles)	Area of Impaired Lake (in acres)	Designated Use Standard[3]	Parameter(s) Exceeding Use Standard[2]
a	Stream	Colorado River (Parashant Canyon to Diamond Creek)	28[4]	NA	A&W	SSC

Notes:

NA = Not Applicable
[1] Water quality samples collected between 1976 and 2001.
[2] As = Arsenic
SSC = Suspended sediment concentration
[3] A&W = Aquatic and Wildlife
[4] Total length of the impaired reach. This reach forms a portion of the border with the Coconino Plateau Basin.

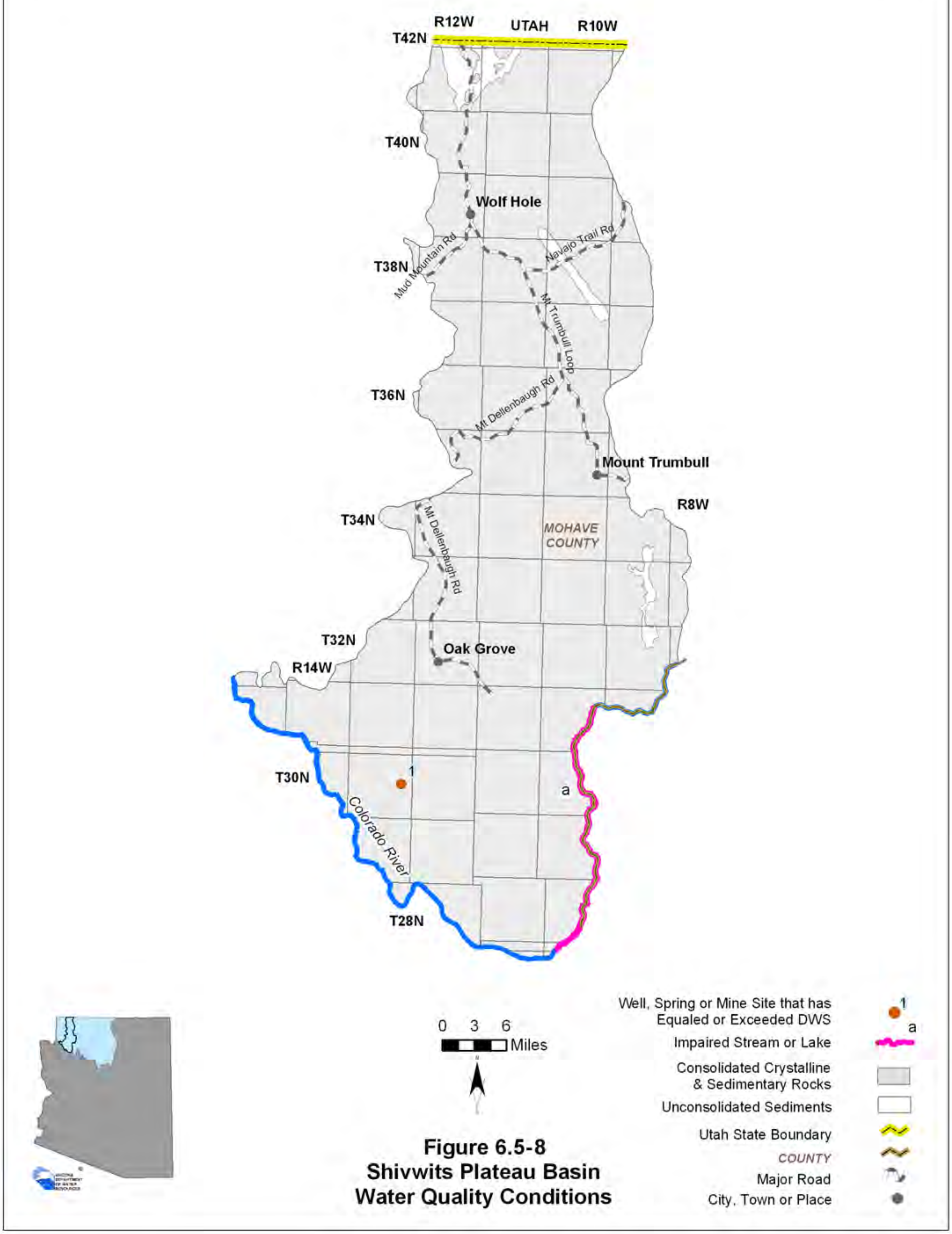


Figure 6.5-8
Shivwits Plateau Basin
Water Quality Conditions

6.5.8 Cultural Water Demands in the Shivwits Plateau Basin

Cultural water demand data including population, number of wells and the average well pumpage and surface water diversions by the municipal, industrial and agricultural sectors are shown in Table 6.5-8. There is no recorded effluent generation in this basin. The USGS National Gap Analysis Program, the primary source of cultural demand map data, showed no demand centers for this basin. A description of cultural water demand data sources and methods is found in Volume 1, Section 1.3.5. More detailed information on cultural water demands is found in Section 6.0.7.

Cultural Water Demands

- Refer to Table 6.5-8
- Population in this basin is very small, with 12 residents in 2000. Projections suggest a small increase in population through 2050.
- There are no recorded surface water uses in this basin. All groundwater use is for municipal demand and has remained relatively constant since 1971.
- As of 2003 there were 18 registered wells with a pumping capacity of less than or equal to 35 gallons per minute and no wells with a pumping capacity of more than 35 gallons per minute.

Table 6.5-8 Cultural Water Demands in the Shivwits Plateau Basin[1]

<table>
<tr><th rowspan="3">Year</th><th rowspan="3">Recent (Census) and Projected (DES) Population</th><th colspan="2" rowspan="2">Number of Registered Water Supply Wells Drilled</th><th colspan="7">Average Annual Demand (in acre-feet)</th></tr>
<tr><th colspan="3">Well Pumpage</th><th colspan="3">Surface-Water Diversions</th><th rowspan="2">Data Source</th></tr>
<tr><th>Q ≤ 35 gpm</th><th>Q > 35 gpm</th><th>Municipal</th><th>Industrial</th><th>Irrigation</th><th>Municipal</th><th>Industrial</th><th>Irrigation</th></tr>
<tr><td>1971</td><td></td><td rowspan="10">16[2]</td><td rowspan="10">0[2]</td><td colspan="3" rowspan="5"><500</td><td colspan="3" rowspan="5">NR</td><td rowspan="20">ADWR (1994)</td></tr>
<tr><td>1972</td><td></td></tr>
<tr><td>1973</td><td></td></tr>
<tr><td>1974</td><td></td></tr>
<tr><td>1975</td><td></td></tr>
<tr><td>1976</td><td></td><td colspan="3" rowspan="5"><500</td><td colspan="3" rowspan="5">NR</td></tr>
<tr><td>1977</td><td></td></tr>
<tr><td>1978</td><td></td></tr>
<tr><td>1979</td><td></td></tr>
<tr><td>1980</td><td>4</td></tr>
<tr><td>1981</td><td>4</td><td rowspan="5">0</td><td rowspan="5">0</td><td colspan="3" rowspan="5"><500</td><td colspan="3" rowspan="5">NR</td></tr>
<tr><td>1982</td><td>5</td></tr>
<tr><td>1983</td><td>5</td></tr>
<tr><td>1984</td><td>6</td></tr>
<tr><td>1985</td><td>6</td></tr>
<tr><td>1986</td><td>6</td><td rowspan="5">0</td><td rowspan="5">0</td><td colspan="3" rowspan="5"><500</td><td colspan="3" rowspan="5">NR</td></tr>
<tr><td>1987</td><td>7</td></tr>
<tr><td>1988</td><td>7</td></tr>
<tr><td>1989</td><td>8</td></tr>
<tr><td>1990</td><td>8</td></tr>
<tr><td>1991</td><td>8</td><td rowspan="5">1</td><td rowspan="5">0</td><td rowspan="5"><300</td><td rowspan="5">NR</td><td rowspan="5">NR</td><td colspan="3" rowspan="5">NR</td><td rowspan="13">USGS (2005)</td></tr>
<tr><td>1992</td><td>9</td></tr>
<tr><td>1993</td><td>9</td></tr>
<tr><td>1994</td><td>10</td></tr>
<tr><td>1995</td><td>10</td></tr>
<tr><td>1996</td><td>10</td><td rowspan="5">0</td><td rowspan="5">0</td><td rowspan="5"><300</td><td rowspan="5">NR</td><td rowspan="5">NR</td><td colspan="3" rowspan="5">NR</td></tr>
<tr><td>1997</td><td>11</td></tr>
<tr><td>1998</td><td>11</td></tr>
<tr><td>1999</td><td>12</td></tr>
<tr><td>2000</td><td>12</td></tr>
<tr><td>2001</td><td>13</td><td rowspan="3">0</td><td rowspan="3">0</td><td rowspan="3"><300</td><td rowspan="3">NR</td><td rowspan="3">NR</td><td colspan="3" rowspan="3">NR</td></tr>
<tr><td>2002</td><td>13</td></tr>
<tr><td>2003</td><td>14</td></tr>
<tr><td>2010</td><td>18</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>2020</td><td>27</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>2030</td><td>40</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>2040</td><td>61</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>2050</td><td>91</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="2">ADDITIONAL WELLS:[3]</td><td>1</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="2">TOTALS:</td><td>18</td><td>0</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
</table>

[1] Does not include evaporation losses from stockponds and reservoirs.

[2] Includes all wells through 1980.

[3] Other water-supply wells are listed in the ADWR Well Registry for this basin, but they do not have completion dates. These wells are summed here.

NR - Not reported

Table 6.5-9 Effluent Generation in the Shivwits Plateau Basin

Facility Name	Ownership	City/Location Served	Population Served	Volume Treated/Generated (acre-feet)	Disposal Method								Current Treatment Level	Population Not Served	Year of Record
					Water-course	Evaporation Pond	Irrigation	Golf Course	Municipal Reuse	Wildlife Area	Discharged to Another Facility	Infiltration Basins			
No Wastewater Treatment Facilities Identified by ADWR in this Basin															

6.5.9 Water Adequacy Determinations in the Shivwits Plateau Basin

There are no water adequacy applications on file with the Department as of May, 2005 for the Shivwits Plateau Basin. A description of the Water Adequacy Program is found in Volume 1, Appendix A. Adequacy determination data sources and methods are found in Volume 1, Section 1.3.1.

Table 6.5-10. Adequacy Determinations in the Shivwits Plateau Basin

Map Key	Subdivision Name	County	Location			No. of Lots	ADWR File No.	ADWR Adequacy	Reason(s) for Inadequacy	Date of Determination	Water Provider at the Time of
			Township	Range	Section						
None identified by ADWR at this time											

Shivwits Plateau Basin
References and Supplemental Reading

References

A

Arizona Corporation Commission (ACC), 2005, Annual reports, Private Sewer companies, 1990 to 2005: ACC Utilities Division.

______, 2005, Annual reports, Small water providers, 1990 to 2005: ACC Utilities Division.

Arizona Crop and Livestock Reporting Service, 1973, 1972 Arizona Agricultural Statistics: Bulletin S-8.

Arizona Department of Economic Security (DES), 2005, Workforce Informer: Data file, accessed August 2005, http://www.workforce.az.gov.*

Arizona Department of Environmental Quality, 2005, Active dairy farms & feedlots: Data file, received October 2005.

______, 2005, ADEQSWI: Data file, received September 2005.

______, 2005, ADEQWATP: Data file, received May 2005.

______, 2005, ADEQWWTP: Data file, received August 2005.

______, 2005, Azurite: Data file, received September 2005.

______, 2005, Effluent dependent waters: GIS cover, received December 2005.

______, 2005, Impaired lakes and reaches: GIS cover, received January 2006.*

______, 2005, Surface water sources used by water providers: Data file, received June 2005.

______, 2005, WWTP and permit files: Miscellaneous working files, received July 2005.

______, 2004, Water providers with arsenic concentrations in wells over 10ppb: Data file, received August 2004.

______, 2004, Water quality exceedences by watershed: Data file, received June 2004.*

______, 2004, Water quality exceedences for drinking water providers in Arizona: Data file, received September 2004.*

Arizona Department of Mines and Mineral Resources (ADMMR), 2005, Active mines in Arizona: Database, accessed at http:// www.admmr.state.az.us.

Arizona Department of Water Resources (ADWR), 2006, Assured and adequate water supply applications: Project files, ADWR Hydrology Division.

______, 2005, Agricultural Surface Water Use Estimates: Unpublished analysis, ADWR Office of Resource Assessment Planning.

______, 2005, Automated recorder sites: Data files, ADWR Basic Data Unit.*

______, 2005, 2004 rural water provider questionnaire: Data files, ADWR Office of Resource Assessment Planning.

______, 2005, Assured and adequate water supply determinations: Database, ADWR Office of Assured and Adequate Water Supply.

______, 2005, Flood warning gages: Database, ADWR Office of Water Engineering.

______, 2005, Inspected dams: Database, ADWR Office of Dam Safety.

______, 2005, Non-jurisdictional dams: Database, ADWR Office of Dam Safety.

______, 2005, Groundwater Site Inventory (GWSI): Database, ADWR Hydrology Division.*

_____, 2005, Registry of surface water rights: ADWR Office of Water Management.*

_____, 2005, Water Protection Fund: Database, ADWR Office of Drought, Conservation and Riparian Planning.

_____, 2005, Water use by golf courses in rural Arizona: Unpublished analysis, ADWR Office of Regional Strategic Planning.

_____, 2005, Wells55: Database.*

_____, 2002, Groundwater quality exceedences in rural Arizona from 1975 to 2001: Data file, ADWR Office of Regional Strategic Planning.*

_____, 1994, Arizona Water Resources Assessment, Vol. I, Inventory and Analysis.*

_____, 1994, Arizona Water Resources Assessment, Vol. II, Hydrologic Summary.*

_____, 1990, Draft outline of basin profiles for the state water assessment: ADWR Statewide Planning Division, Memorandum to L. Linser, D.W., January, 16, 1990.*

Arizona Game and Fish Department (AGF), 2005, Arizona Waterways: Data file, received April 2005.

_____, 1997 & 1993, Statewide riparian inventory and mapping project: GIS cover.*

_____, 1982, Arizona Lakes Classification Study.

Arizona Land Resource Information System (ALRIS), 2005, Springs: GIS cover, accessed January 2006 at http://www.land.state.az.us/alris/index.html.*

_____, 2005, Streams: GIS cover, accessed 2005 at http://www.land.state.az.us/alris/index.html.*

_____, 2005, Water features: GIS cover, accessed July 2005 at http://www.land.state. az.us/alris/index.html.*

_____, 2004, Land ownership: GIS cover, accessed in 2004 at http://www.land.state.az.us/alris/index.html.*

Arizona Meteorological Network (AZMET), 2005, Arizona climate stations: Pan evaporation data, accessed December 2005 at http://www.ag.arizona.edu/ azmet/locate.html.

Arizona Water Commission, 1975, Summary, Phase I, Arizona State Water Plan, Inventory of resource and uses.

D

Diroll, M., and Marsh, D., 2006, Status of water quality in Arizona-2004 integrated 305(b) assessment and 303(d) listing report: ADEQ report.

E

Environmental Protection Agency (EPA), 2005, Surf Your Watershed: Facility reports, accessed April 2005 at http://oaspub.epa.gov/enviro/ef_home2.water.

_____, 2000 and 1996, Clean Watershed Needs Survey: datasets, accessed March 2005 at http://www.epa.gov/owm/mtb/cwns/index.htm.

F

Fisk, G.G., Duet, D.W., Evans, C.E., Angernoth, N.K., and Longsworth, S.A., 2004, Water Resources Data, Arizona Water Year 2003: USGS Water-Data Report AZ-03-1.*

K

Konieczki, A.D. and Wilson, R.P., 1992, Annual summary of ground-water conditions in

Arizona, spring 1986 to spring 1987: USGS Open File Report 92-54.*

M

McCormack, H.F., Fisk, G.G., Duet, N.R., Evans, D.W., Roberts, W.P., and Castillo, N.K., 2002, Water resources data Arizona, water year 2002: USGS Water Data Report AZ-02-1.*

N

Natural Resources Conservation Service (NRCS), 2005, SNOTEL (Snowpack Telemetry) stations: Data file, accessed December 2005 at http://www3.wcc.nrcs.usda.gov /nwcc/sntlsites.jsp?state=AZ.

______, 2005, Snow Course stations: Data file, accessed December 2005 at http://www.wcc.nrcs.usda.gov/nwcc/snow-course-sites.jsp?state=AZ

O

Oregon State University, Spatial Climate Analysis Service (SCAS), 2006, Average annual precipitation in Arizona for 1961-1990: PRISM GIS cover, accessed in 2006 at www.ocs.orst.edu/prism.*

P

Pope, G.L., Rigas, P.D., and Smith, C.F., 1998, Statistical summaries of streamflow data and characteristics of drainage basins for selected streamflow-gaging stations in Arizona through water year 1996: USGS Water Resources Investigations Report 98-4225.*

T

Tadayon, S., 2004, Water withdrawals for irrigation, municipal, mining, thermoelectric-power, and drainage uses in Arizona outside of the active management areas, 1991-2000: USGS Scientific Investigations Report 2004-5293, 27 pp.*

U

US Army Corps of Engineers, 2004 and 2005, National Inventory of Dams: Arizona Dataset, accessed November 2004 to April 2005 at http://crunch.tec.army.mil /nid/webpages/nid.cfm

US Geological Survey (USGS), 2006, Average annual runoff in the United States, 1951-1980: Data file, accessed March 2006 at http://aa179.cr.usgs.gov/metadata/ wrdmeta/runoff.htm.*

______, 2006, Springs and spring discharges: Dataset, received November 2004 and January 2006 from USGS office in Tucson, AZ.*

______, 2006, National Hydrography Dataset: Arizona dataset, accessed at http://nhd.usgs.gov/.*

______, 2005, National Water Information System (NWIS): Arizona dataset, accessed December 2005 at http://waterdata.usgs.gov/nwis.*

______, 2004, Southwest Regional Gap analysis study- land cover descriptions: Electronic file, accessed January 2005 at http://earth.gis.usu.edu/swgap.*

______, 1981, Geographic digital data for 1:500,000 scale maps: USGS National Mapping Program Data Users Guide.*

V

Valencia, R.A., Wennerlund, J.A., Winstead, R.A., Woods, S., Riley, L., Swanson, E., and Olson, S., 1993, Arizona riparian inventory and mapping project: Arizona Game and Fish Department.*

W

Wahl, C.R., Boe, S.R., Wennerlund, R.A., Winstead, R.A., Allison, L.J., Kubly, D.M., 1997, Remote sensing mapping of Arizona intermittent stream riparian areas: Arizona Game and Fish Technical Report 112.*

Water Infrastructure Finance Authority of Arizona (WIFA), 2005, Clean Watershed Needs Survey-2004: Unpublished data sheets, received July 2005.

Wenrich, K.J., Boundt, S.Q., and others, 1994, Hydrochemical survey for mineralized breccia pipes - data from springs, wells and streams on the Hualapai Indian Reservation, Northwestern Arizona: USGS Open File Report 93-619.*

Western Regional Climate Center (WRCC), 2005, Pan evaporation stations: Data file accessed December 2005 at http://www4.ncdc.noaa.gov/cgi-win/wwcgi.dll?wwDI~GetCity~USA.

_____, 2005, Precipitation and temperature stations: Data file, accessed December 2005 at http://www4.ncdc.noaa.gov/cgi-win/wwcgi.dll?wwDI~GetCity~USA.

Wilson, R.P., 1992, Summary of groundwater conditions in Arizona 1985 to 1986: USGS Water Resources Investigation Report, 90-4179.*

*All references marked with an asterisk contain information that was directly used in the basin summaries, tables or maps.

Supplemental Reading

Andersen, Mark, 2005, Assessment of water availability in the Lower Colorado River basin: in Conservation and Innovation in Water Management: Proceedings of the 18th annual Arizona Hydrological Society Symposium, Flagstaff, Arizona, September, 2005.

Blanchard, P.J., 1986, Groundwater conditions in the Kaiparowits Plateau area, Utah and Arizona, with emphasis on the Navajo Sandstone: Utah Department of Natural Resources Technical Publication No. 81, 87 p.

Bureau of Land Management, 2007, Final resource management plan and Environmental Impact Statement for Vermilion Cliffs National Monument, and the Grand Canyon Parashant National Monument: BLM Arizona Field Office and NPS joint report, 2007.

Bureau of Reclamation, 2002, Grand Canyon National Park water supply appraisal study, Coconino, Mohave and Yavapai Counties, Arizona: Grand Canyon National Park report.

Enzel, Y., Ely, L.L., House, P.K., Baker, V.R., and Webb, R.H., 1993, Paleoflood evidence for a natural upper bound to flood magnitudes in the Colorado River Basin: Water Resources Research, vol. 29, no. 7, p. 2287-2297.

Freilich, Leitner & Carlisle, 2005, Mohave County General Plan: Water Resources Element.

Gauger, R.W., 1997, River-stage data Colorado River, Glen Canyon Dam to upper Lake Mead, Arizona, 1990-1994: USGS Open–File Report 96-626, 20 p.

Grand Canyon Wildlands Council, 2002, Arizona Strip springs, seeps and natural ponds: Inventory, assessment and development of recovery priorities: Arizona Water Protection Fund Project 99-074.

Hart, R.J., 1999, Water Quality of the Colorado River monitored by the USGS National Stream Quality Accounting Network: in Water Issues and Partnerships for Rural Arizona: Proceedings of the 12 annual symposium of the Arizona Hydrological Society, September 1999, Hon Dah, Arizona.

Hereford, R., Webb, G., and Graham, S., 2002, Precipitation history of the Colorado Plateau region, 1990 – 2000: USGS Fact sheet 119-02.

Inglis, R., 1997, Monitoring and analysis of spring flows at Pipe Springs NM, Arizona: NPS Technical Report NPS/NRWRD/NRTR-97125, 35 p.

Moore, K., Davis, B., Duck, T., 2003, Mt. Trumbull Ponderosa Pine Ecosystem Restoration Project: USDA Forest Service Proceedings RMRS-P-29 2003.

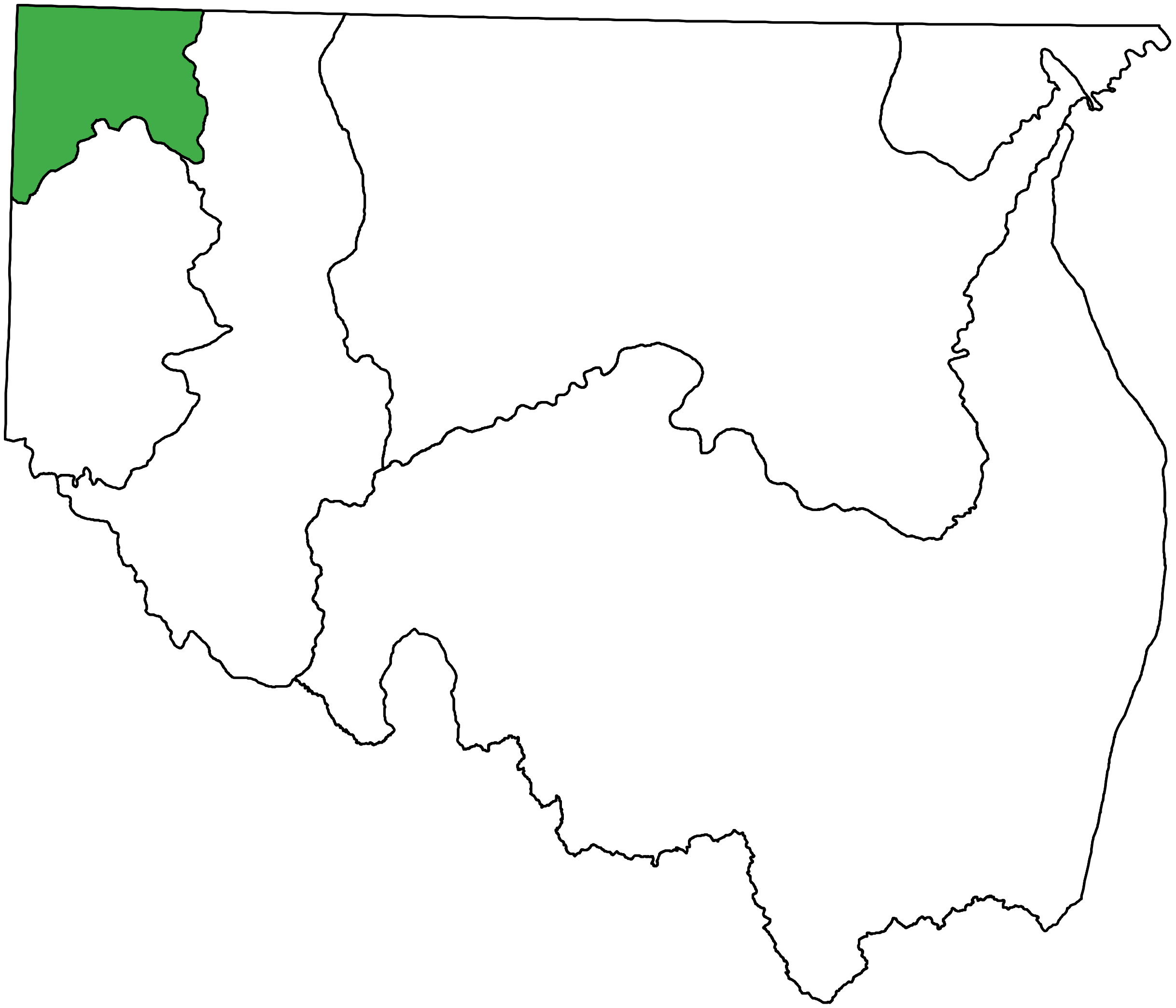
Rust Engineering Co., 1970, Preliminary study development of water resources, Kaibab-Paiute Indian Reservation, Arizona: US Dept. of Commerce, Economic Development Administration Report, 23 p.

Smith J.D., and Wiele, S., 1991, Flow and sediment transport in the Colorado River between Lake Powell and Lake Mead: USGS report 38 p.

Rote, J.J., Flynn, M.E., and Bills, D.J., 1997, Hydrologic data, Colorado River and major tributaries, Glen Canyon Dam to Diamond Creek, Arizona, water years 1990-1995: USGS Open – File Report 97-250, 474 p.

Index to Section 6.0

Section 6.6
Virgin River Basin



6.6.1 Geography of the Virgin River Basin

The Virgin River Basin, located in the northwestern-most part of the planning area is 434 square miles in area. Geographic features and principal communities are shown on Figure 6.6-1. The basin is characterized by mountains and a broad valley west of the mountains. Vegetation is primarily Mohave desertscrub with smaller areas of Great Basin desertscrub, Great Basin conifer woodland, interior chaparral and a small area of Rocky Mountain montane conifer forest. (See Figure 6.0-9) Riparian vegetation along the Virgin River is predominantly tamarisk.

- Principal geographic features shown on Figure 6.6-1 are:
    - Principal basin communities of Beaver Dam and Littlefield
    - The Virgin River running from the northeast to southwest of the basin
    - Virgin and Beaver Dam Mountains in the center of the basin
    - Mt. Bangs on the southern basin boundary, the highest point in the basin at 8,012 feet

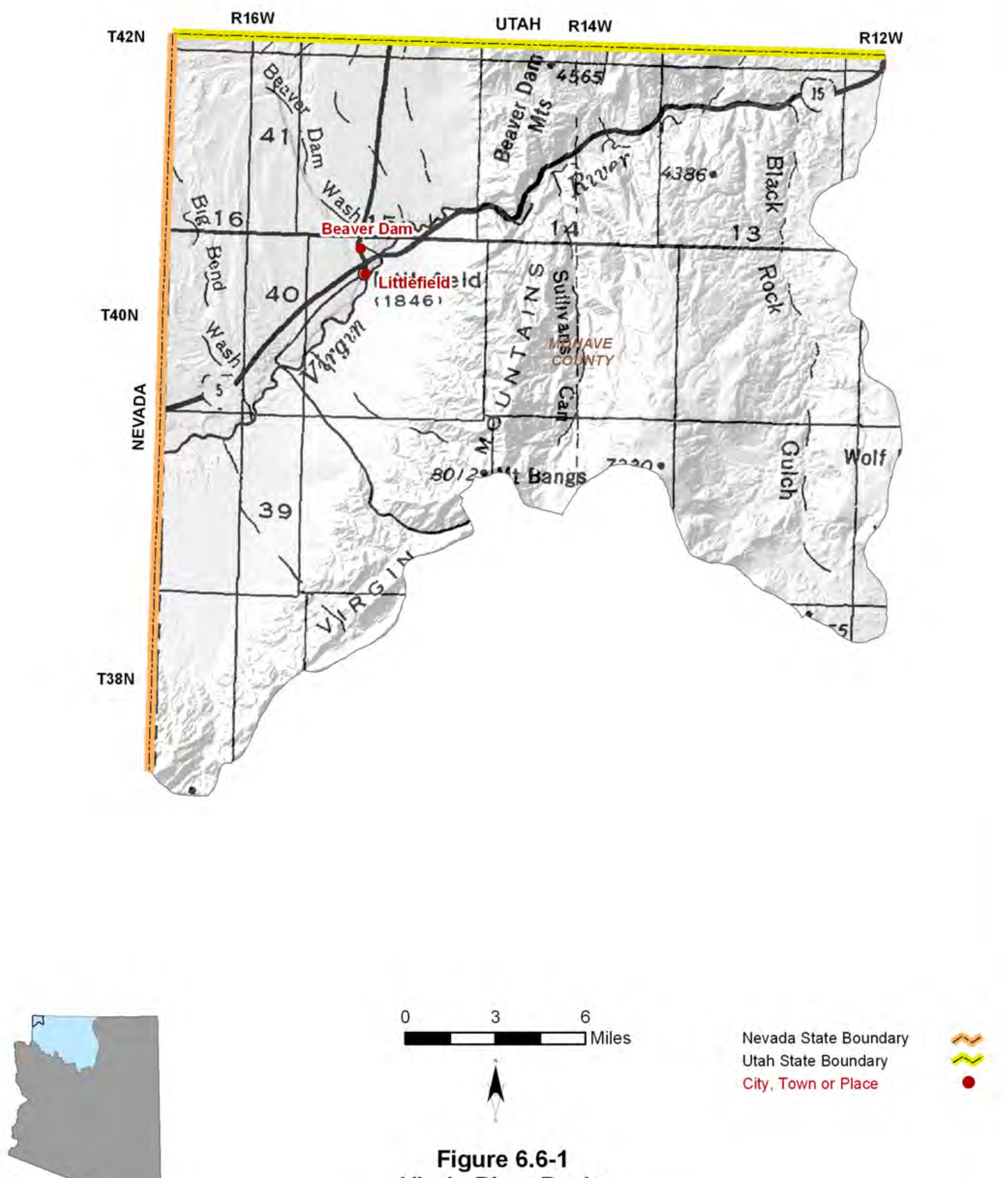


Figure 6.6-1
Virgin River Basin
Geographic Features

6.6.2 Land Ownership in the Virgin River Basin

Land ownership, including the percentage of ownership by category, for the Virgin River Basin is shown in Figure 6.6-2. The principal feature of land ownership in this basin is the large portion of land managed by the U.S. Bureau of Land Management. A description of land ownership data sources and methods is found in Volume 1, Section 1.3.8. Land ownership categories are discussed below in the order of percentage from largest to smallest in the basin.

U.S. Bureau of Land Management (BLM)

- 91.7% of the land is federally owned and managed by the Arizona Strip Field Office of the Bureau of Land Management.
- A small portion of BLM land is managed as the Grand Canyon-Parashant National Monument. The basin includes the 19,600 acre Beaver Dam Mountains Wilderness and a portion of the 87,900 acre Paiute Wilderness, located in the eastern portion of the basin.
- Primary land use is recreation, resource conservation and grazing.

Private

- 5.0% of the land is private.
- The majority of the private land is in the vicinity of Beaver Dam/Littlefield and west of Elbow Canyon Road in an area known as “Scenic.”
- Land uses include domestic, commercial and agriculture.

State Trust Land

- 3.3% of the land is held in trust for the public schools under the State Trust Land system.
- State land is located throughout most of the basin and is interspersed with BLM and private lands.
- Primary land use is grazing.

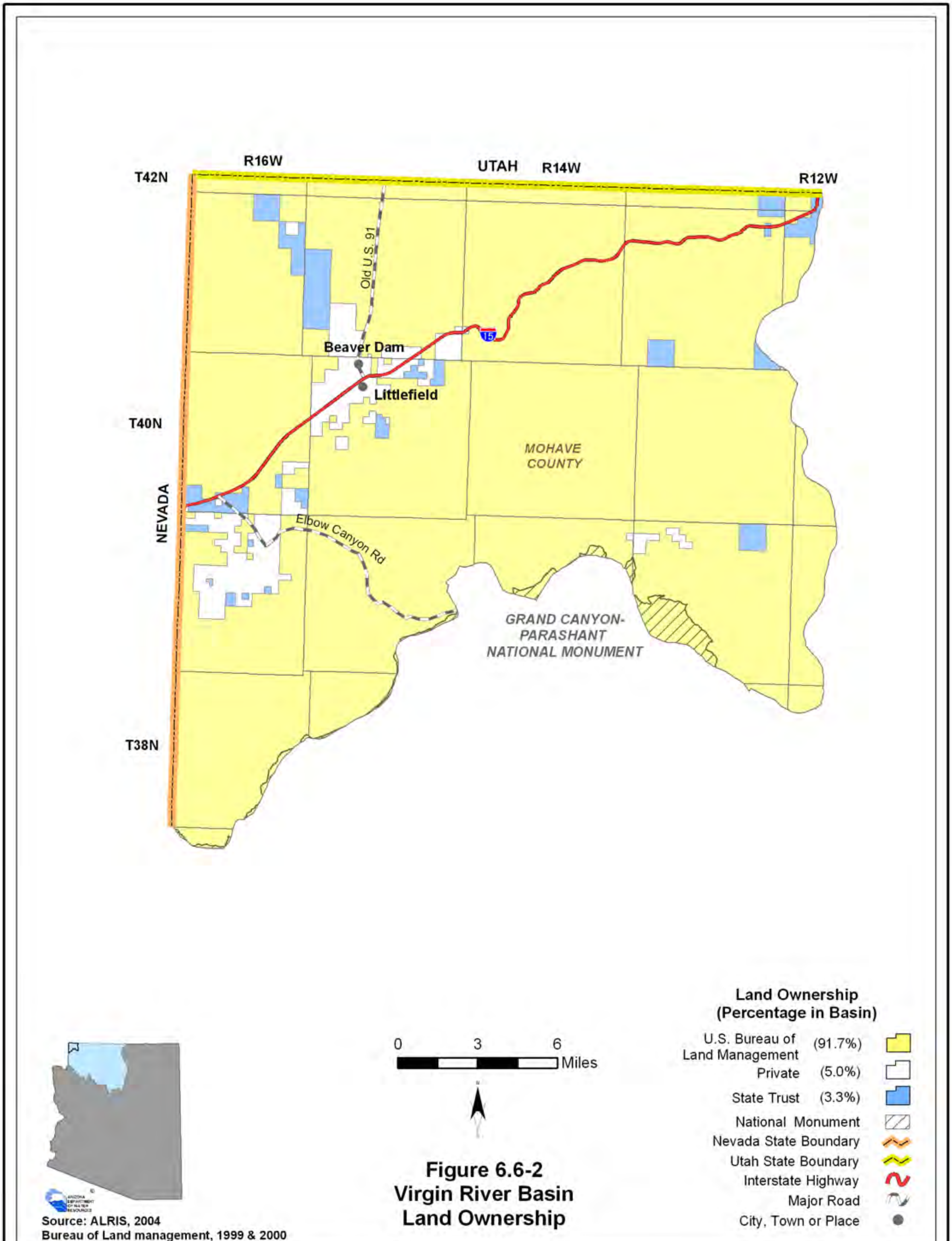


Figure 6.6-2
Virgin River Basin Land Ownership

6.6.3 Climate of the Virgin River Basin

Climate data from NOAA/NWS Co-op Network stations are complied in Table 6.6-1 and the locations are shown on Figure 6.6-3. Figure 6.6-3 also shows precipitation contour data from the Spatial Climate Analysis Service (SCAS) at Oregon State University. The Virgin River Basin does not contain Evaporation Pan, AZMET or SNOTEL/Snowcourse stations. A description of the climate data sources and methods is found in Volume 1, Section 1.3.3.

NOAA/NWS Co-op Network

- Refer to Table 6.6-1A
- Temperatures at the one NOAA/NWS Co-op Network station range from an average annual high of 89.5°F to an average annual low of 45.5°F.
- The highest average seasonal rainfall occurs in the winter season (January-March) when 40% of the annual rainfall occurs. Average annual rainfall is 7.59 inches.

SCAS Precipitation Data

- See Figure 6.6-3
- Additional precipitation data shows average annual rainfall as high as 16 inches in the eastern portion of the basin and as low as four inches in the western portion of the basin.

Table 6.6-1 Climate Data for the Virgin River Basin

A. NOAA/NWS Co-op Network:

Station Name	Elevation (in feet)	Period of Record Used for Averages	Average Temperature Range (in F)		Average Precipitation (in inches)				
			Max/Month	Min/Month	Winter	Spring	Summer	Fall	Annual
Beaver Dam	1,880	1971-2000	89.5/Jul	45.5/Jan	3.05	0.89	1.68	1.97	7.59

Source: WRCC, 2003

B. Evaporation Pan:

Station Name	Elevation (in feet)	Period of Record Used for Averages	Avg. Annual Evap (in inches)
None			

Source: WRCC, 2003.

C. AZMET:

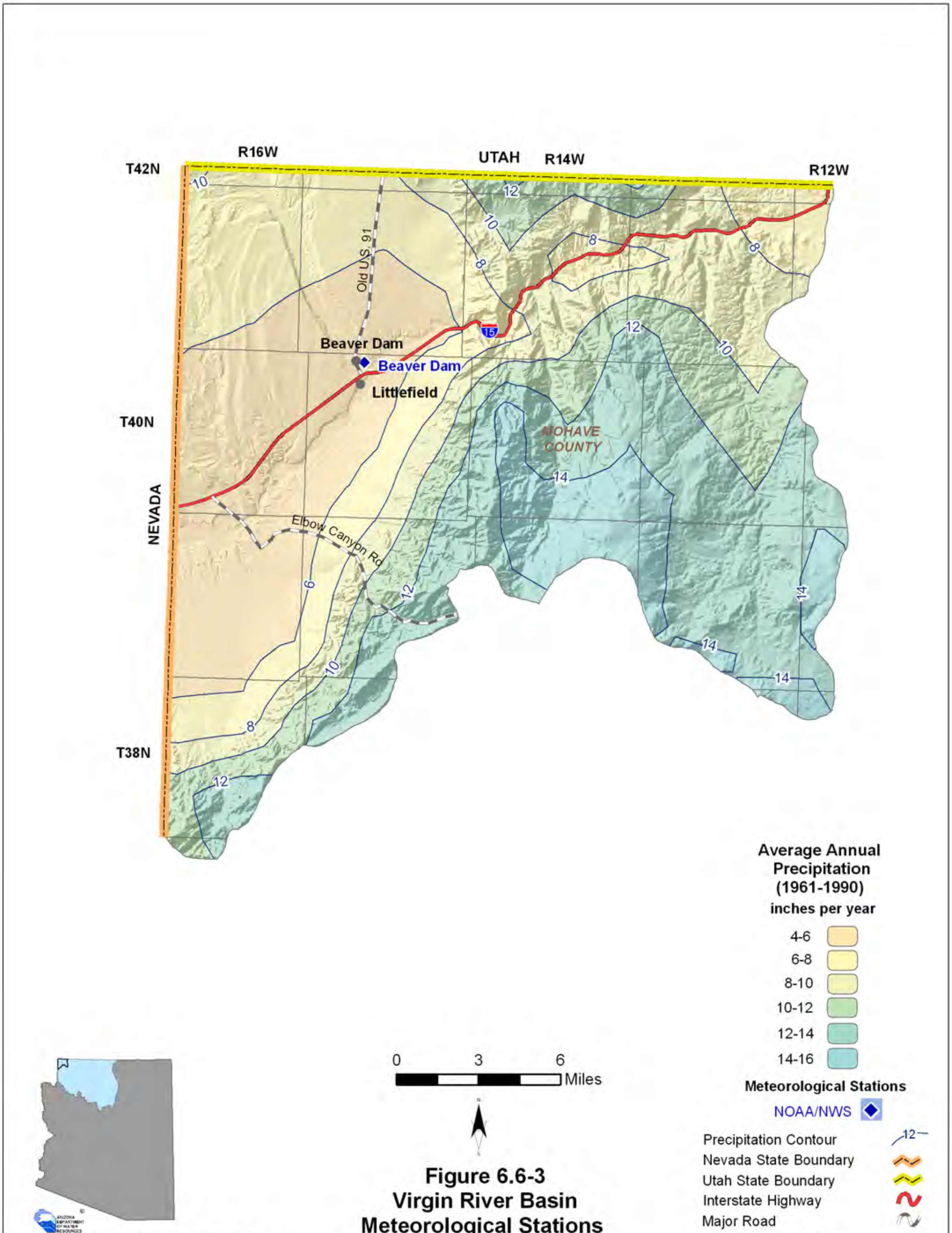
Station Name	Elevation (in feet)	Period of Record Used for Averages	Average Annual Reference Evaportranspiration, in inches (N*umber of years to calculate averages*)
None			

Source: Arizona Meteorological Network, 2005

D. SNOTEL/Snowcourse:

Station Name	Elevation (in feet)	Period of Record Used for Averages	Average Snowpack, at Beginning of the Month, as Inches Snow Water Content *(Number of measurements to calculate average)*					
			Jan.	Feb.	March	April	May	June
None								

Source: NRCS, 2005



Precipitation Data Source: Oregon State University, 1998

Figure 6.6-3
Virgin River Basin
Meteorological Stations
and Annual Precipitation

6.6.4 Surface Water Conditions in the Virgin River Basin

Streamflow data, including average seasonal flow, average annual flow and other information are shown in Table 6.6-2. Flood ALERT equipment in the basin is shown in Table 6.6-3. Reservoir and stockpond data, including maximum storage or maximum surface area, are shown in Table 6.6-4. The location of streamflow gages identified by USGS number, flood ALERT equipment, USGS runoff contours and large reservoirs are shown on Figure 6.6-5. A description of stream data sources and methods is found in Volume 1, Section 1.3.16. A description of reservoir data sources and methods is found in Volume 1, Section 1.3.11. A description of stockpond data sources and methods is found in Volume 1, Section 1.3.15.

Streamflow Data

- Refer to Table 6.6-2.
- Data from three stations located at two watercourses are shown in the table and on Figure 6.6-5. Two stations are real-time stations and all are currently operating.
- In general, average seasonal flow is highest in the winter (January-March) when between 31% and 42% of the average annual flow occurs.
- The maximum annual flow was 506,912 acre-feet in 1983 at the Virgin River at Littlefield station with a contributing drainage area of 5,090 square miles. Data shown on the table is through the 2002-2003 water year. In 2005, the annual flow at this station was 566,225 acre-feet or approximately four times greater than the median annual flow.
- Figure 6.6-4 shows the periodic flood events in the Virgin River recorded at the Littlefield gage from 1930-2006.

Flood ALERT Equipment

- Refer to Table 6.6-3.
- As of October 2005 there was one weather station in the basin located at Beaver Dam.

Reservoirs and Stockponds

- Refer to Table 6.6-4.
- There are no large reservoirs and one small reservoir with a total surface area of six acres.
- There are 45 registered stockponds in the basin.

Runoff Contour

- Refer to Figure 6.6-5.
- Average annual runoff is highest, 0.5 inches per year or 27 acre-feet per square mile, at the southeastern tip of the basin and decreases to 0.1 inches, or five acre-feet per square mile, to the north and west.

Figure 6.6-4 Annual Flows (acre-feet) Virgin River at Littlefield, Arizona, water years 1930-2006 (Station # 9415000)

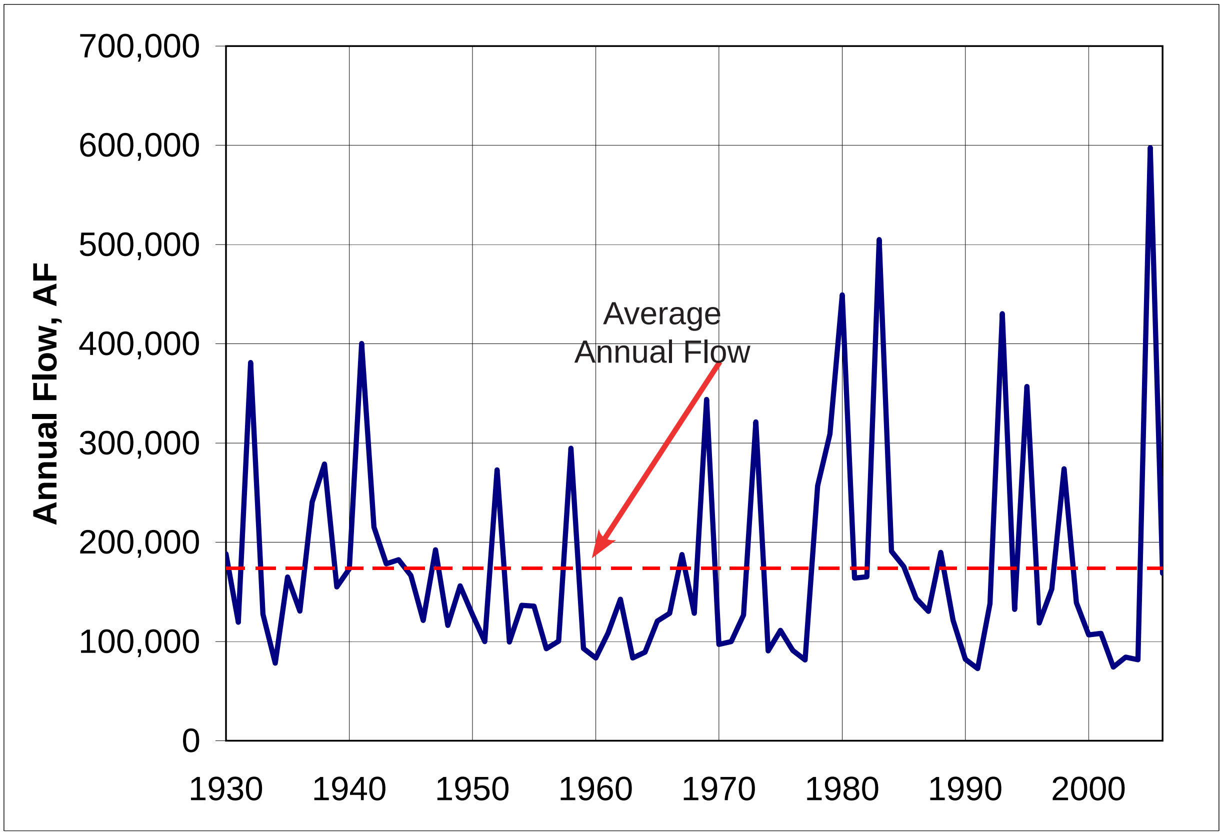


Table 6.6-2 Streamflow Data for the Virgin River Basin

Station Number	USGS Station Name	Drainage Area (in mi^2)	Mean Basin Elevation (in feet)	Period of Record	Average Seasonal Flow (% of annual flow)				Annual Flow (in acre-feet/year)				Years of Record
					Winter	Spring	Summer	Fall	Minimum	Median	Mean	Maximum	
9413700	Virgin River above the Narrows near Littlefield	4,415	NA	6/1998-current (real time)	31	21	19	29	68,506 (2000)	71,764	92,644	137,663 (2001)	3
9414900	Beaver Dam Wash at Beaver Dam	575	NA	2/1993-current (real time)	42	21	17	20	1,151 (2002)	1,709	1,572	1,947 (1996)	5
9415000	Virgin River at Littlefield	5,090	5,500	10/1929-current	32	33	15	20	73,140 (1977)	141,935	174,502	506,912 (1983)	72

Sources: USGS NWIS, USGS 1998 and USGS 2003.

Notes:
NA = Not available
Statistics based on Calendar Year
Annual Flow statistics based on monthly values
Summation of Average Annual Flows may not equal 100 due to rounding.
Period of record may not equal Year of Record used for annual Flow/Year statistics due to only using years with a 12 month record

Table 6.6-3 Flood ALERT Equipment in the Virgin River Basin

Station ID	Station Name	Station Type	Install Date	Responsibility
7570	Beaver Dam	Weather Station	NA	Mohave County FCD

Notes:
FCD = Flood Control District
NA = Not available at this time

Table 6.6-4 Reservoirs and Stockponds in the Virgin River Basin

A. Large Reservoirs (500 acre-feet capacity and greater)

MAP KEY	RESERVOIR/LAKE NAME *(Name of dam, if different)*	OWNER/OPERATOR	MAXIMUM STORAGE (AF)	USE	JURISDICTION
None identified by ADWR at this time					

B. Other Large Reservoirs (50 acre surface area or greater)[1]

MAP KEY	RESERVOIR/LAKE NAME *(Name of dam, if different)*	OWNER/OPERATOR	MAXIMUM SURFACE AREA (acres)	USE	JURISDICTION
None identified by ADWR at this time					

C. Small Reservoirs (greater than 15 acre-feet and less than 500 acre-feet capacity)

Total number: 0
Total maximum storage: 0 acre-feet

D. Other Small Reservoirs (between 5 and 50 acres surface area)[1]

Total number: 1
Total surface area: 6 acres

E. Stockponds (up to 15 acre-feet capacity)

Total number: 45

[1] Capacity data not available to ADWR

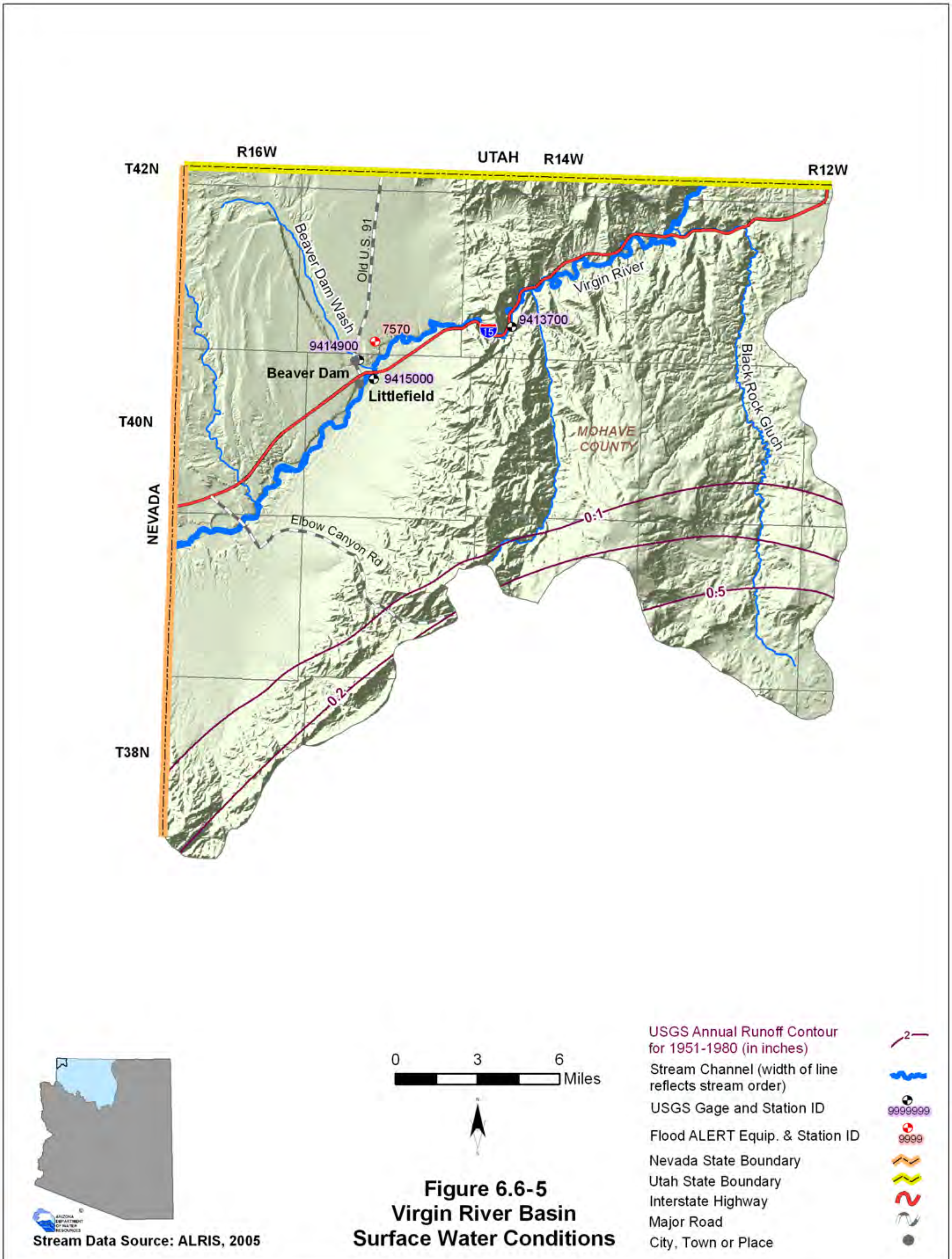


Figure 6.6-5
Virgin River Basin
Surface Water Conditions

6.6.5 Perennial/Intermittent Streams and Major Springs in the Virgin River Basin

Major springs with discharge rates and date of measurement and the total number of springs in the basin are shown in Table 6.6-5. The locations of major springs and perennial streams are shown on Figure 6.6-6. A description of data sources and methods for intermittent and perennial reaches is found in Volume 1, Section 1.3.16. A description of spring data sources and methods is found in Volume 1, Section 1.3.14.

- There are no intermittent streams and the only perennial stream is the Virgin River.
- There are a series of major springs in the basin with a combined discharge rate of 50 gallons per minute (gpm). The largest discharge is in the vicinity of Littlefield, where the total discharge for eight springs is between 8,980 gpm and 22,400 gpm.
- There are no minor springs in the basin.
- The total number of springs, regardless of discharge, identified by the USGS varies from 23 to 25, depending on the database reference.

Table 6.6-5 Springs in the Virgin River Basin

A. Major Springs (10 gpm or greater):

Map Key	Name	Location		Discharge (in gpm)[1]	Date Discharge Measured
		Latitude	Longitude		
1	Littlefield (multiple)	365539	1134950	8,980 - 22,400[2]	During or before 2000
2	Beaver Dam Wash (multiple)	365411	1135615	1,120[3]	During or before 1997

B. Minor Springs (1 to 10 gpm):

Name	Location		Discharge (in gpm)[2]	Date Discharge Measured
	Latitude	Longitude		
None identified by ADWR at this time				

C. Total number of springs, regardless of discharge, identified by USGS (see ALRIS, 2005 and NHD, 2006): 23 to 25

Notes:

[1] Most recent measurement identified by ADWR

[2] Discharge of 8 springs in a 7 mile reach from the Narrows to the Littlefield gage

[3] Estimation of discharge along Beaver Dam Wash above Littlefield gage

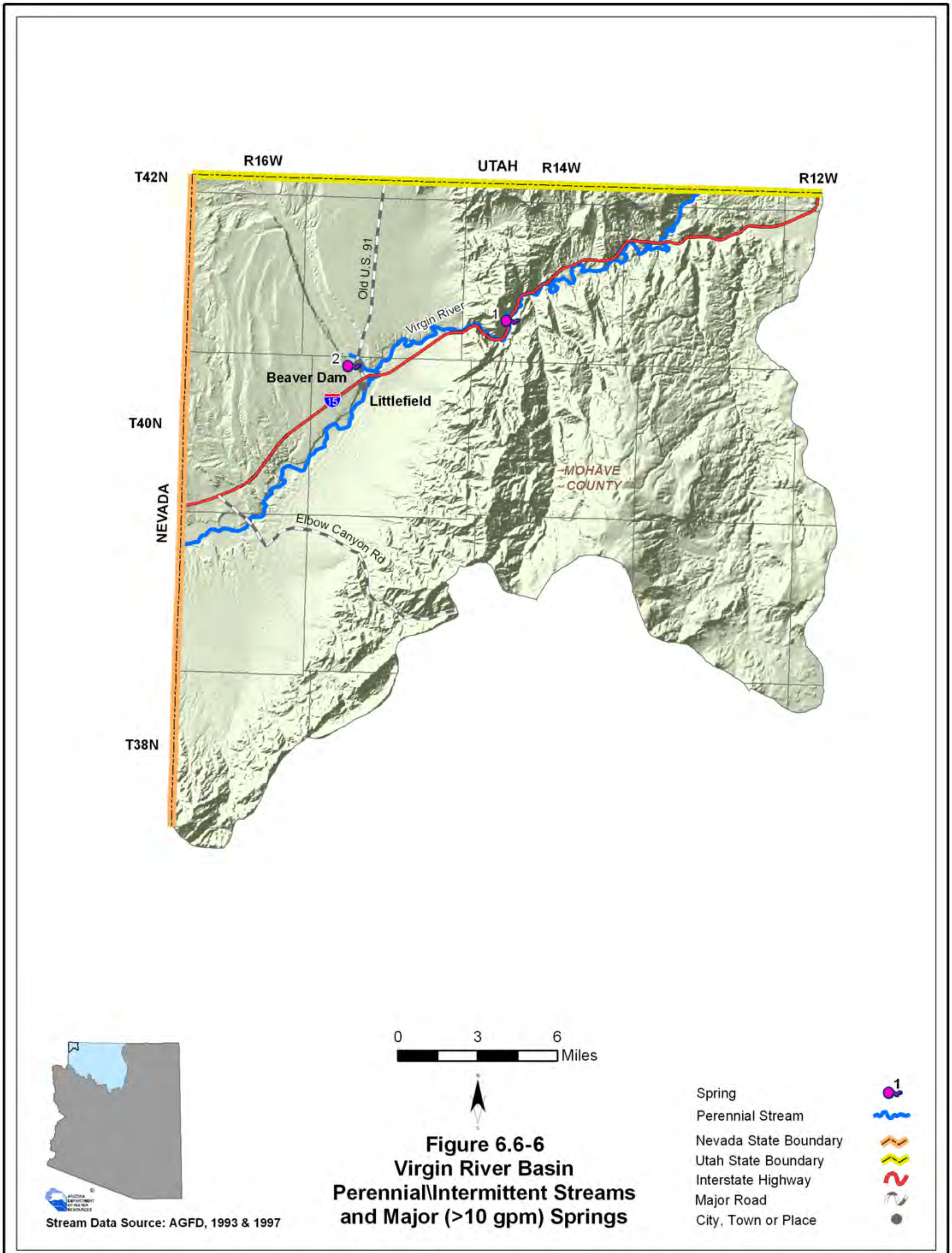


**Figure 6.6-6
Virgin River Basin
Perennial\Intermittent Streams
and Major (>10 gpm) Springs**

6.6.6 Groundwater Conditions of the Virgin River Basin

Major aquifers, well yields, estimated natural recharge, estimated water in storage, number of index wells and date of last water-level sweep are shown in Table 6.6-6. Figure 6.6-7 shows aquifer flow direction and water-level change between 1990-1991 and 2003-2004. Figure 6.6-8 contains hydrographs for selected wells shown on Figure 6.6-7. Figure 6.6-9 shows well yields in five yield categories. A description of aquifer data sources and methods is found in Volume 1, Section 1.3.2. A description of well data sources and methods, including water-level changes and well yields, is found in Volume 1, Section 1.3.19.

Major Aquifers
- Refer to Table 6.6-6 and Figure 6.6-7.
- Major aquifers in the basin include basin fill and sedimentary rock (Muddy Creek Formation).
- Basin geology in the western portion of the basin consists of unconsolidated sediments.
- Flow direction is generally toward the west following Beaver Dam Wash and the Virgin River.

Well Yields
- Refer to Table 6.6-6 and Figure 6.6-9.
- As shown on Figure 6.6-9, well yields in this basin range from less than 100 gallons per minute (gpm) to greater than 2,000 gpm.
- One source of well yield information, based on 53 reported wells, indicates that the median well yield in this basin is 650 gpm.

Natural Recharge
- Refer to Table 6.6-6.
- The natural recharge estimate for this basin is greater than 30,000 acre-feet per year.

Water in Storage
- Refer to Table 6.6-6.
- According to the one estimate of water in storage for this basin, from a 1994 ADWR study, there is 1.7 million acre-feet of water in storage to a depth of 1,200 feet.

Water Level
- Refer to Figure 6.6-7. Water levels are shown for wells measured in 2003-2004.
- The Department annually measures six index wells in this basin. Depth to water and hydrographs for five of the six index wells are shown in Figure 6.6-7 and Figure 6.6-8.
- The deepest recorded water level in the basin is 380 feet in the northern portion of the basin and the shallowest is 57 feet north of Beaver Dam.
- There is one ADWR automated groundwater level monitoring device located near Littlefield, not shown on the map.

Table 6.6-6 Groundwater Data for the Virgin River Basin

<table>
<tr><th>Basin Area, in square miles:</th><td colspan="2">434</td></tr>
<tr><th rowspan="3">Major Aquifer(s):</th><th colspan="2">Name and/or Geologic Units</th></tr>
<tr><td colspan="2">Basin Fill</td></tr>
<tr><td colspan="2">Sedimentary Rock (Muddy Creek Formation)</td></tr>
<tr><th rowspan="4">Well Yields, in gal/min:</th><td>N/A</td><td>Measured by ADWR and/or USGS</td></tr>
<tr><td>Range 3-5,500
Median 650
(53 wells reported)</td><td>Reported on registration forms for large (> 10-inch) diameter wells</td></tr>
<tr><td>Range 0-2,000</td><td>ADWR (1990 and 1994)</td></tr>
<tr><td>Range 0-2,500</td><td>USGS (1994)</td></tr>
<tr><th>Estimated Natural Recharge, in acre-feet/year:</th><td>>30,000</td><td>Virgin Valley Water District (2005)</td></tr>
<tr><th rowspan="2">Estimated Water Currently in Storage, in acre-feet:</th><td>1,700,000 (to 1,200 ft)</td><td>ADWR (1994)</td></tr>
<tr><td>N/A</td><td>Arizona Water Commission (1975)</td></tr>
<tr><th>Current Number of Index Wells:</th><td colspan="2">6</td></tr>
<tr><th>Date of Last Water-level Sweep:</th><td colspan="2">1991 (65 wells measured)</td></tr>
</table>

N/A = Not Available

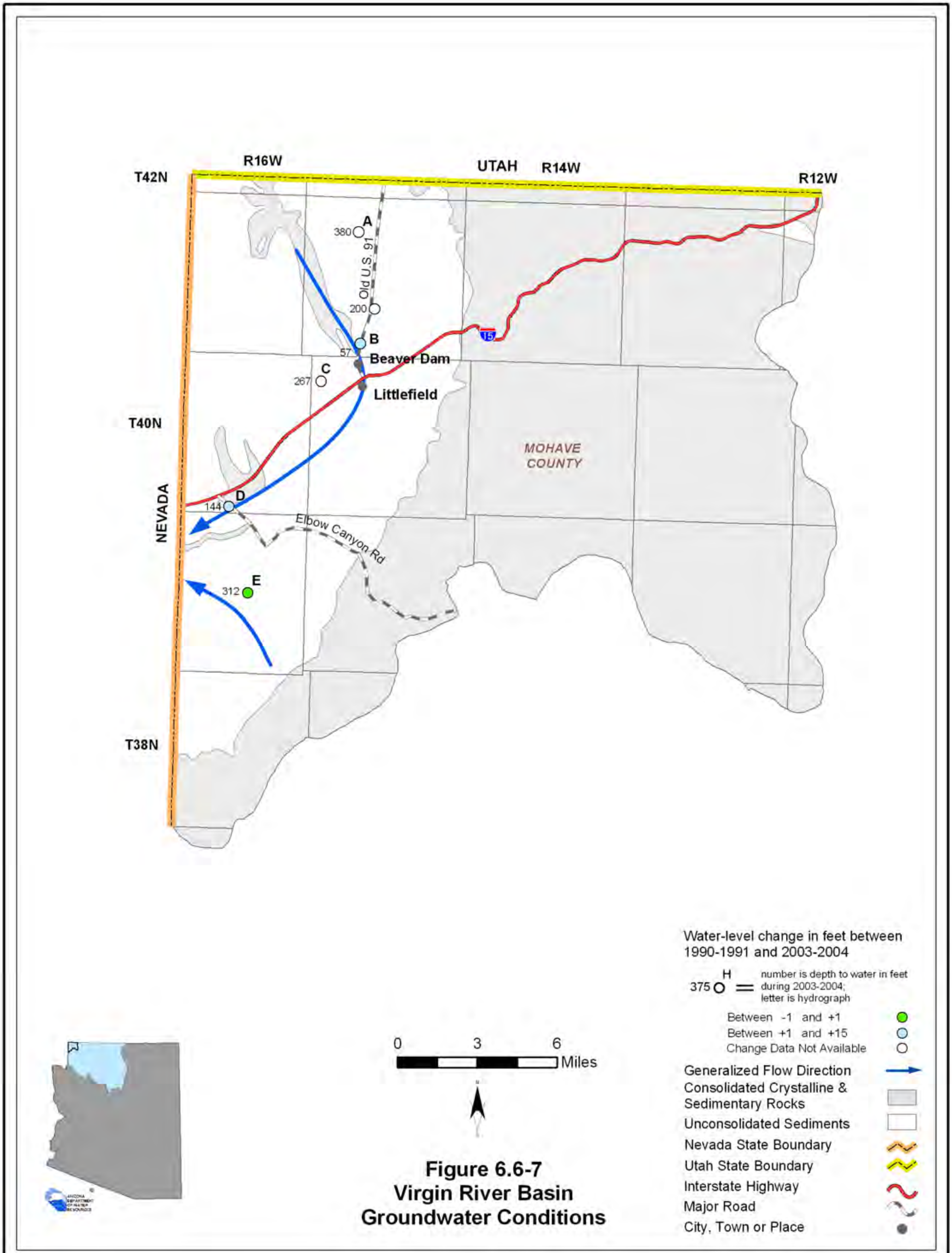
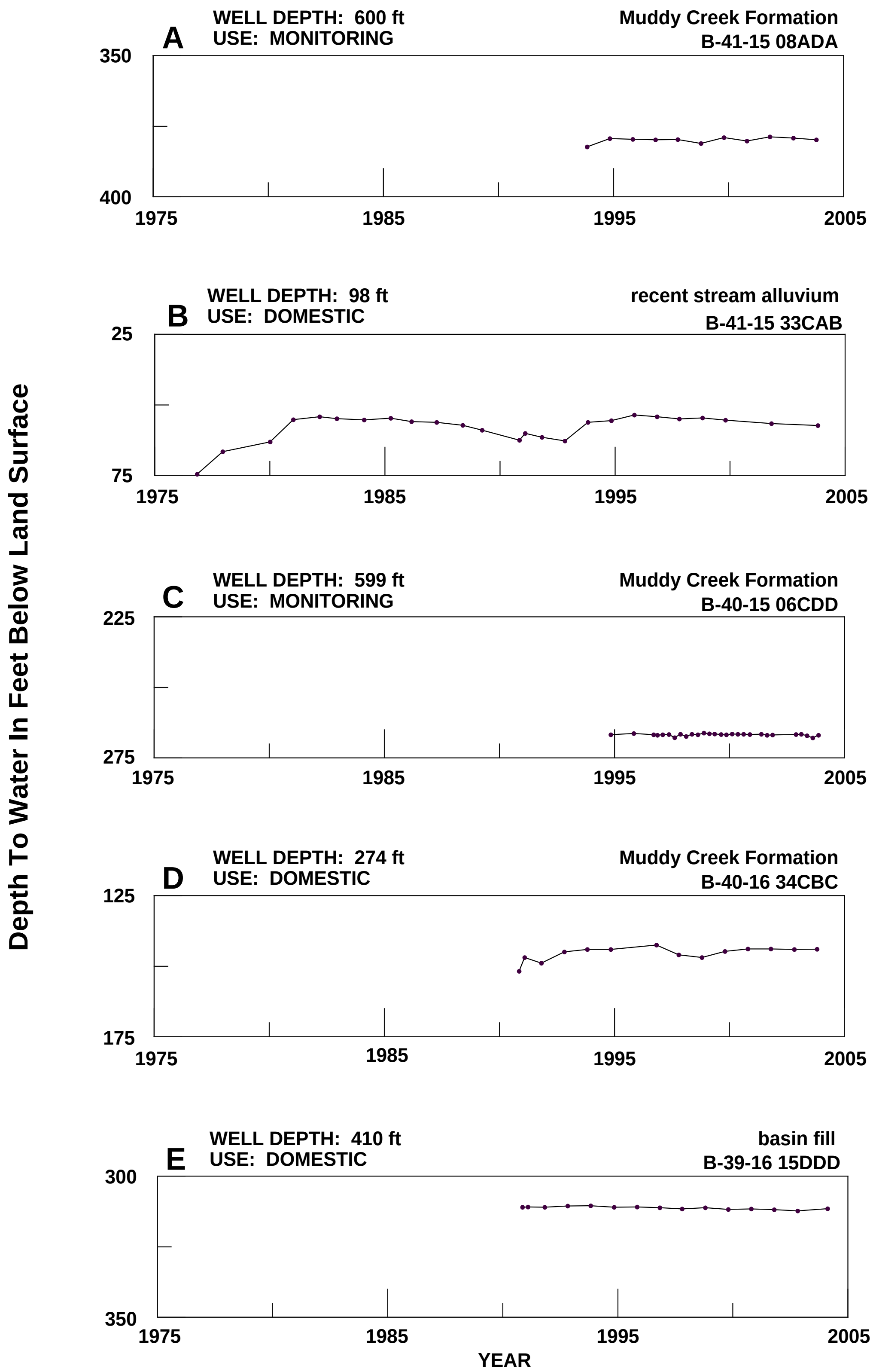


Figure 6.6-7
Virgin River Basin
Groundwater Conditions

Figure 6.6-8
Virgin River Basin
Hydrographs Showing Depth to Water in Selected Wells



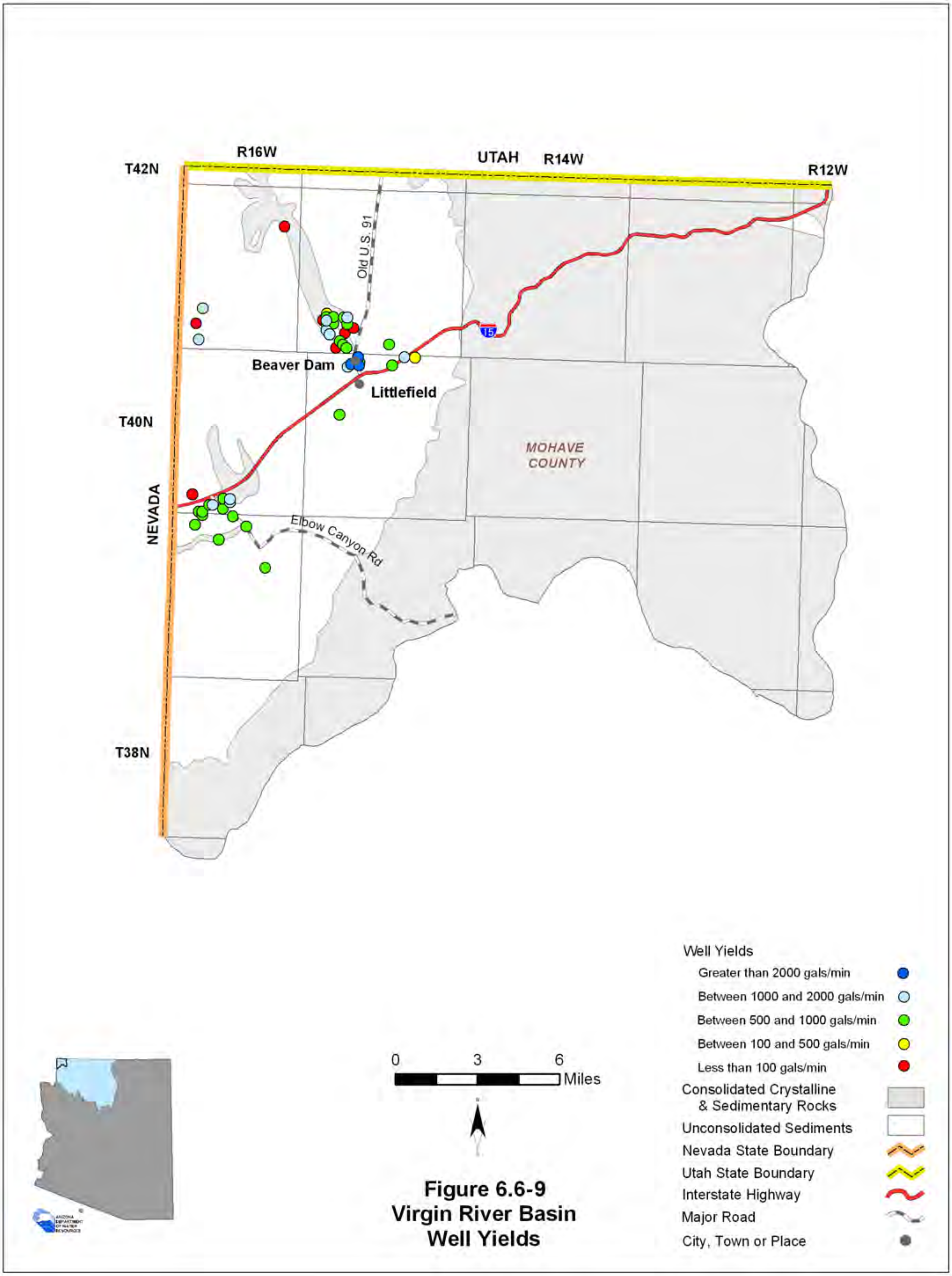


Figure 6.6-9
Virgin River Basin
Well Yields

6.6.7 Water Quality of the Virgin River Basin

Wells, springs and mine sites with parameter concentrations that have equaled or exceeded drinking water standard(s), including location and parameter(s) are shown in Table 6.6-7A. Impaired lakes and streams with site type, name, length of impaired reach, area of impaired lake, designated use standard and parameter(s) exceeded is shown in Table 6.6-7B. Figure 6.6-10 shows the location of water quality occurrences keyed to Table 6.6-7. A description of water quality data sources and methods is found in Volume 1, Section 1.3.18. Not all parameters were measured at all sites; selective sampling for particular constituents is common.

Wells, Springs and Mines

- Refer to Table 6.6-7A.
- Thirteen wells have parameter concentrations that have equaled or exceeded drinking water standards.
- The most common standard equaled or exceeded was arsenic.
- Other standards equaled or exceeded were radionuclides, nitrates and lead.

Lakes and Streams

- Refer to Table 6.6-7B.
- Water quality standards were exceeded in one 10-mile stream reach, the Virgin River from Beaver Dam Wash to Big Bend Wash.
- The parameters exceeded were suspended sediment concentration and selenium.
- This reach is not part of the ADEQ water quality improvement effort called the Total Maximum Daily Load (TMDL) Program at this time.

Table 6.6-7 Water Quality Exceedences in the Virgin River Basin[1]

A. Wells, Springs and Mines

Map Key	Site Type	Site Location			Parameter(s) Concentration has Equaled or Exceeded Drinking Water Standard (DWS)[2]
		Township	Range	Section	
1	Well	41 North	15 West	32	As
2	Well	41 North	15 West	32	As
3	Well	40 North	15 West	3	As, Rad
4	Well	40 North	15 West	3	As
5	Well	40 North	15 West	3	As
6	Well	40 North	15 West	4	As
7	Well	40 North	15 West	5	As
8	Well	40 North	15 West	5	As
9	Well	40 North	16 West	33	NO3
10	Well	39 North	16 West	3	Pb
11	Well	39 North	16 West	11	As
12	Well	39 North	16 West	11	As
13	Well	39 North	16 West	15	As

B. Lakes and Streams

Map Key	Site Type	Site Name	Length of Impaired Stream Reach (in miles)	Area of Impaired Lake (in acres)	Designated Use Standard[3]	Parameter(s) Exceeding Use Standard[2]
a	Stream	Virgin River (Beaver Dam Wash to Big Bend Wash)	10	NA	A&W	Se, SSC

Notes:

NA = Not Applicable
[1] Water quality samples collected between 1997 and 2002.
[2] As = Arsenic
NO3 = Nitrate/ Nitrite
Rad = One or more of the following radionuclides - Gross Alpha, Gross Beta, Radium, and Uranium
Se = Selenium
SSC = Suspended Sediment Concentration
[3] A&W = Aquatic and Wildlife

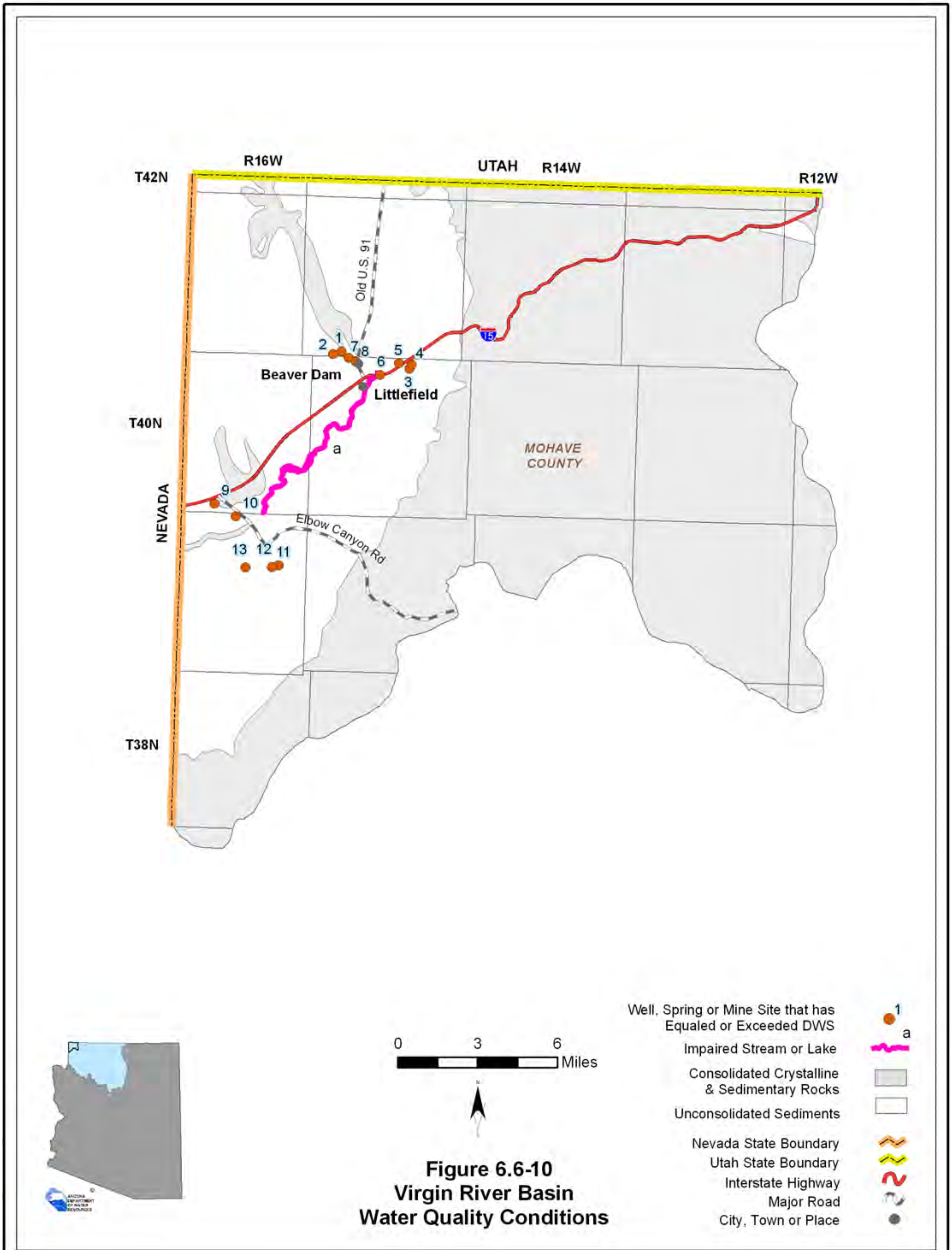


Figure 6.6-10
Virgin River Basin
Water Quality Conditions

6.6.8 Cultural Water Demands in the Virgin River Basin

Cultural water demand data including population, number of wells and the average well pumpage and surface water diversions by the municipal, industrial and agricultural sectors are shown in Table 6.6-8. Effluent generation including facility ownership, location, population served and not served, volume treated, disposal method and treatment level is shown in Table 6.6-9. Figure 6.6-11 shows the location of demand centers. A description of cultural water demand data sources and methods is found in Volume 1, Section 1.3.5. More detailed information on cultural water demands is found in Section 6.0.7.

Cultural Water Demands

- Refer to Table 6.6-8 and Figure 6.6-11.
- Population in this basin increased from 99 in 1980 to 1,532 in 2000 and is projected to reach 5,508 by 2050.
- Groundwater demand increased from 5,000 acre-feet per year on average in 1971-1975 to approximately 9,150 acre-feet per year on average from 1996-2000. In 2001-2003 groundwater demand was 2,950 acre-feet per year on average.
- Surface water demand was 3,000 acre-feet on average from 1971-1990 and increased to approximately 6,350 acre-feet in 1996-2000. In 2001-2003 surface water use was approximately 1,650 acre-feet per year on average due to declining agricultural demand.
- Most basin demand for both surface water and groundwater is for irrigation. Agricultural demand centers are found in the vicinity of Beaver Dam/Littlefield and Elbow Canyon Road. Flooding in January 2005 destroyed some of the agricultural fields in this basin.
- All recorded industrial demand in the basin is for two golf courses.
- There are two sand and gravel operations in the basin in the vicinity of Scenic and Beaver Dam, their water use was not available.
- As of 2003 there were 258 registered wells with a pumping capacity of less than or equal to 35 gallons per minute and 82 wells with a pumping capacity of more than 35 gallons per minute.

Effluent Generation

- Refer to Table 6.6-9.
- There are four wastewater treatment facilities in this basin.
- Information on population served, effluent generation and disposal method is available only for the Beaver Dam Sewer Company Wastewater Treatment Plant. This plant serves 119 people, generates 6.2 acre-feet of effluent and discharges to a watercourse.

Table 6.6-8 Cultural Water Demands in the Virgin River Basin[1]

<table>
<tr><th rowspan="3">Year</th><th rowspan="3">Recent (Census) and Projected (DES) Population</th><th colspan="2" rowspan="2">Number of Registered Water Supply Wells Drilled</th><th colspan="7">Average Annual Demand (in acre-feet)</th></tr>
<tr><th colspan="3">Well Pumpage</th><th colspan="3">Surface-Water Diversions</th><th rowspan="2">Data Source</th></tr>
<tr><th>Q ≤ 35 gpm</th><th>Q > 35 gpm</th><th>Municipal</th><th>Industrial</th><th>Irrigation</th><th>Municipal</th><th>Industrial</th><th>Irrigation</th></tr>
<tr><td>1971</td><td></td><td rowspan="10">37[2]</td><td rowspan="10">51[2]</td><td colspan="3" rowspan="5">5,000</td><td colspan="3" rowspan="5">3,000</td><td rowspan="20">ADWR (1994)</td></tr>
<tr><td>1972</td><td></td></tr>
<tr><td>1973</td><td></td></tr>
<tr><td>1974</td><td></td></tr>
<tr><td>1975</td><td></td></tr>
<tr><td>1976</td><td></td><td colspan="3" rowspan="5">6,000</td><td colspan="3" rowspan="5">3,000</td></tr>
<tr><td>1977</td><td></td></tr>
<tr><td>1978</td><td></td></tr>
<tr><td>1979</td><td></td></tr>
<tr><td>1980</td><td>99</td></tr>
<tr><td>1981</td><td>109</td><td rowspan="5">9</td><td rowspan="5">11</td><td colspan="3" rowspan="5">6,000</td><td colspan="3" rowspan="5">3,000</td></tr>
<tr><td>1982</td><td>119</td></tr>
<tr><td>1983</td><td>129</td></tr>
<tr><td>1984</td><td>139</td></tr>
<tr><td>1985</td><td>150</td></tr>
<tr><td>1986</td><td>160</td><td rowspan="5">48</td><td rowspan="5">10</td><td colspan="3" rowspan="5">7,000</td><td colspan="3" rowspan="5">3,000</td></tr>
<tr><td>1987</td><td>170</td></tr>
<tr><td>1988</td><td>180</td></tr>
<tr><td>1989</td><td>190</td></tr>
<tr><td>1990</td><td>200</td></tr>
<tr><td>1991</td><td>333</td><td rowspan="5">72</td><td rowspan="5">6</td><td rowspan="5"><300</td><td rowspan="5">700</td><td rowspan="5">7,800</td><td rowspan="5">NR</td><td rowspan="5"><300</td><td rowspan="5">5,800</td><td rowspan="13">USGS (2005)</td></tr>
<tr><td>1992</td><td>466</td></tr>
<tr><td>1993</td><td>600</td></tr>
<tr><td>1994</td><td>733</td></tr>
<tr><td>1995</td><td>866</td></tr>
<tr><td>1996</td><td>999</td><td rowspan="5">43</td><td rowspan="5">3</td><td rowspan="5"><300</td><td rowspan="5">700</td><td rowspan="5">8,300</td><td rowspan="5">NR</td><td rowspan="5"><300</td><td rowspan="5">6,200</td></tr>
<tr><td>1997</td><td>1,133</td></tr>
<tr><td>1998</td><td>1,266</td></tr>
<tr><td>1999</td><td>1,399</td></tr>
<tr><td>2000</td><td>1,532</td></tr>
<tr><td>2001</td><td>1,580</td><td rowspan="3">14</td><td rowspan="3">1</td><td rowspan="3"><300</td><td rowspan="3">700</td><td rowspan="3">2,000</td><td rowspan="3">NR</td><td rowspan="3"><300</td><td rowspan="3">1,500</td></tr>
<tr><td>2002</td><td>1,628</td></tr>
<tr><td>2003</td><td>1,676</td></tr>
<tr><td>2010</td><td>1,855</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>2020</td><td>2,435</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>2030</td><td>3,196</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>2040</td><td>4,196</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>2050</td><td>5,508</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="2">***ADDITIONAL WELLS:[3]***</td><td>35</td><td></td><td colspan="7"></td></tr>
<tr><td colspan="2">***WELL TOTALS:***</td><td>258</td><td>82</td><td colspan="7"></td></tr>
</table>

[1] Does not include evaporation losses from stockponds and reservoirs.
[2] Includes all wells through 1980.
[3] Other water-supply wells are listed in the ADWR Well Registry for this basin, but they do not have completion dates. These wells are summed here.
NR - Not reported

Table 6.6-9 Effluent Generation in the Virgin River Basin

Facility Name	Ownership	City/Location Served	Population Served	Volume Treated/Generated (acre-feet)	Disposal Method								Current Treatment Level	Population Not Served	Year of Record
					Water-course	Evaporation Pond	Irrigation	Golf Course	Municipal Reuse	Wildlife Area	Discharged to Another Facility	Infiltration Basins			
Beaver Dam Sewer Co. WWTP	Virgin River ID	Beaver Dam	119	6.2	X								Secondary	NA	2002
Biasi WWTP	Private	Beaver Dam	NA												
Shadow Ridge WWTP	NA	Littlefield	NA												
Virgin Acres WWTP	NA	Beaver Dam	NA												

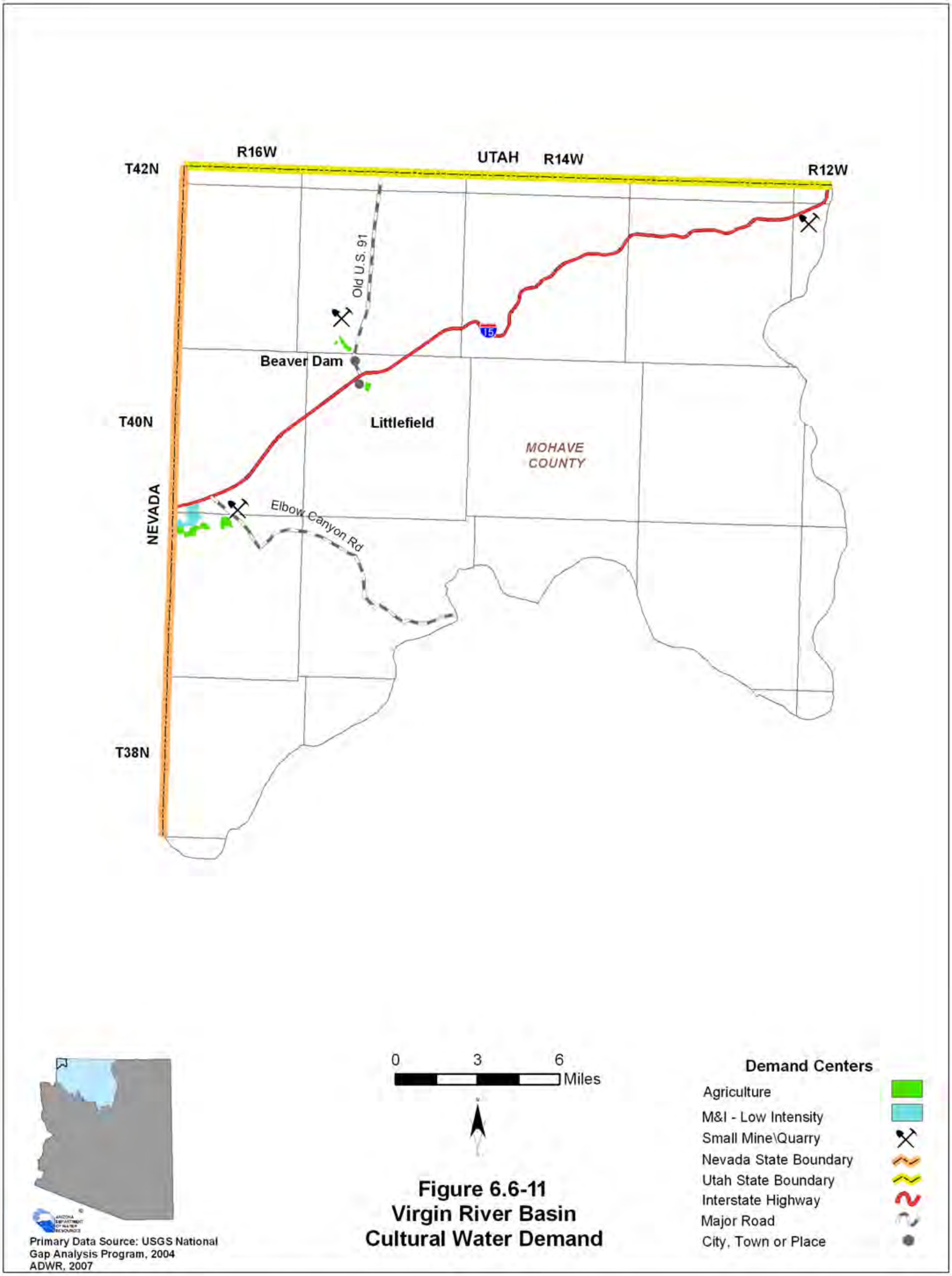


Figure 6.6-11
Virgin River Basin
Cultural Water Demand

6.6.9 Water Adequacy Determinations in the Virgin River Basin

Water adequacy determination information including the subdivision name, location, number of lots, adequacy determination, reason for the inadequacy determination, date of determination and subdivision water provider are shown in Table 6.6-10. Figure 6.6-12 shows the locations of subdivisions keyed to the Table. A description of the Water Adequacy Program is found in Volume 1, Appendix A. Adequacy determination data sources and methods are found in Volume 1, Sections 1.3.1.

Water Adequacy Reports

- See Table 6.6-10
- Nine of the ten water adequacy determinations made for 627 lots total in this basin through May, 2005 were determined to be adequate.
- The one determination of inadequacy was for 26 lots in Mohave County near the boundary with Nevada. The determination of inadequacy was because the applicant chose not to submit the necessary information, and/or the available hydrologic data was insufficient to make a determination.

Table 6.6-10. Adequacy Determinations in the Virgin River Basin[1]

Map Key	Subdivision Name	County	Location			No. of Lots	ADWR File No.[2]	ADWR Adequacy Determination	Reason(s) for Inadequacy Determination[3]	Date of Determination	Water Provider at the Time of Application
			Township	Range	Section						
1	Beaver Dam Estates	Mohave	41 North	15 West	32	48		Adequate		05/06/92	Beaver Dam East Domestic W.I.D.
2	Beaver Dam Oasis	Mohave	41 North	15 West	33	9		Adequate		01/23/92	Dry Lot Subdivision
3	Beaver Dam Resort, Inc.	Mohave	40 North	15 West	4, 5	NA		Adequate		10/01/87	Beaver Dam Water Company
4	Beaver Dam Virgin Acres # 1	Mohave	41 North	15 West	32	51	22-300115	Adequate		07/10/96	Beaver Dam Water Company
5	Biasi Ranch Estates	Mohave	41 North	15 West	29	19	22-401814	Adequate		09/08/05	Biasi Water Company
6	Desert Springs Ranchos	Mohave	40 North	15 West	3	21		Adequate		01/13/94	Dry Lot Subdivision
7	Fairview Mobile Home Estates	Mohave	40 North	16 West	32	26		Inadequate	A1	11/30/87	Mesquite Farmstead Water Association
8	Virgin Acres	Mohave	41 North	15 West	29	320		Adequate		9/25/1995	Biasi Water Company
9	Virgin Acres - B	Mohave	41 North	15 West	32	40	22-300568	Adequate		12/04/98	Beaver Dam Water Company
10	Virgin Village I & II	Mohave	41 North	15 West	32	93	22-300507	Adequate		10/07/98	Biasi Water Company

Notes:
[1] Each determination of the adequacy of water supplies available to a subdivision is based on the information available to ADWR and the standards of review and policies in effect at the time the determination was made. In some cases, ADWR might make a different determination if a similar application were submitted today, based on the hydrologic data and other information currently available, as well as current rules and policies.
[2] Prior to February 1995, ADWR did not assign file numbers to applications for adequacy determination.
[3] A. Physical/Continuous
1) Insufficient Data (applicant chose not to submit necessary information, and/or available hydrologic data insufficient to make determination)
2) Insufficient Supply (existing water supply unreliable or physically unavailable;for groundwater, depth-to-water exceeds criteria)
3) Insufficient Infrastructure (distribution system is insufficient to meet demands or applicant proposed water hauling)
B. Legal (applicant failed to demonstrate a legal right to use the water or failed to demonstrate the provider's legal authority to serve the subdivision)
C. Water Quality
D. Unable to locate records

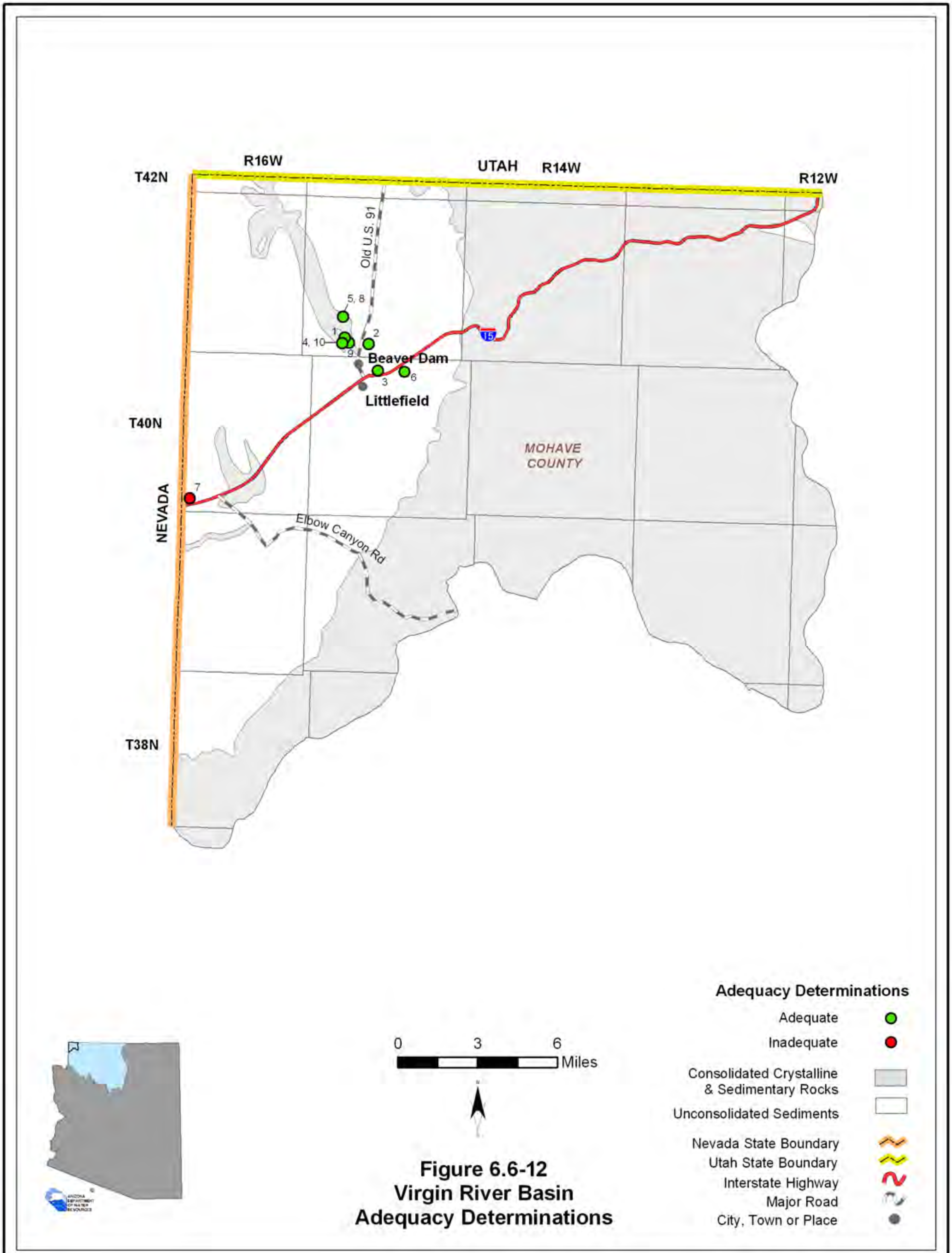


Figure 6.6-12
Virgin River Basin
Adequacy Determinations

Virgin River Basin
References and Supplemental Reading

References

A

Arizona Corporation Commission (ACC), 2005, Annual reports, Private Sewer companies, 1990 to 2005: ACC Utilities Division.*

______, 2005, Annual reports, Small water providers, 1990 to 2005: ACC Utilities Division.*

Arizona Crop and Livestock Reporting Service, 1973, 1972 Arizona Agricultural Statistics: Bulletin S-8.

Arizona Department of Economic Security (DES), 2005, Workforce Informer: Data file, accessed August 2005, http://www.workforce.az.gov.*

Arizona Department of Environmental Quality, 2005, Active dairy farms & feedlots: Data file, received October 2005.

______, 2005, ADEQSWI: Data file, received September 2005.

______, 2005, ADEQWATP: Data file, received May 2005.

______, 2005, ADEQWWTP: Data file, received August 2005.*

______, 2005, Azurite: Data file, received September 2005.

______, 2005, Effluent dependent waters: GIS cover, received December 2005.

______, 2005, Impaired lakes and reaches: GIS cover, received January 2006.*

______, 2005, Surface water sources used by water providers: Data file, received June 2005.

______, 2005, WWTP and permit files: Miscellaneous working files, received July 2005.*

______, 2004, Personal communication with D. Town, ADEQ hydrologist, Aug.13, 2004.*

______, 2004, Water providers with arsenic concentrations in wells over 10ppb: Data file, received August 2004.

______, 2004, Water quality exceedences by watershed: Data file, received June 2004.

______, 2004, Water quality exceedences for drinking water providers in Arizona: Data file, received September 2004.*

Arizona Department of Mines and Mineral Resources (ADMMR), 2005, Active mines in Arizona: Database, accessed at http:// www.admmr.state.az.us.

Arizona Department of Water Resources (ADWR), 2006, Assured and adequate water supply applications: Project files, ADWR Hydrology Division.

______, 2005, Agricultural Surface Water Use Estimates: Unpublished analysis, ADWR Office of Resource Assessment Planning.*

______, 2005, Automated recorder sites: Data files, ADWR Basic Data Unit.*

______, 2005, 2004 rural water provider questionnaire: Data files, ADWR Office of Resource Assessment Planning.

______, 2005, Assured and adequate water supply determinations: Database, ADWR Office of Assured and Adequate Water Supply.*

______, 2005, Flood warning gages: Database, ADWR Office of Water Engineering.*

______, 2005, Inspected dams: Database, ADWR Office of Dam Safety.

______, 2005, Non-jurisdictional dams: Database, ADWR Office of Dam Safety.

______, 2005, Groundwater Site Inventory (GWSI): Database, ADWR Hydrology Division.*

______, 2005, Registry of surface water rights: ADWR Office of Water Management.*

_____, 2005, Water Protection Fund: Database, ADWR Office of Drought, Conservation and Riparian Planning.

_____, 2005, Water use by golf courses in rural Arizona: Unpublished analysis, ADWR Office of Regional Strategic Planning.

_____, 2005, Wells55: Database.*

_____, 2002, Groundwater quality exceedences in rural Arizona from 1975 to 2001: Data file, ADWR Office of Regional Strategic Planning.*

_____, 1994, Arizona Water Resources Assessment, Vol. I, Inventory and Analysis.*

_____, 1994, Arizona Water Resources Assessment, Vol. II, Hydrologic Summary.*

_____, 1990, Draft outline of basin profiles for the state water assessment: ADWR Statewide Planning Division, Memorandum to L. Linser, D.W., January, 16, 1990.*

Arizona Game and Fish Department (AGF), 2005, Arizona Waterways: Data file, received April 2005.

_____, 1997 & 1993, Statewide riparian inventory and mapping project: GIS cover.*

_____, 1982, Arizona Lakes Classification Study.

Arizona Land Resource Information System (ALRIS), 2005, Springs: GIS cover, accessed January 2006 at http://www.land.state.az.us/alris/index.html.*

_____, 2005, Streams: GIS cover, accessed 2005 at http://www.land.state.az.us /alris/index.html.*

_____, 2005, Water features: GIS cover, accessed July 2005 at http://www.land.state.az. us/alris/index.html.*

_____, 2004, Land ownership: GIS cover, accessed in 2004 at http://www.land.state.az.us /alris/index.html.*

Arizona Meteorological Network (AZMET), 2005, Arizona climate stations: Pan evaporation data, accessed December 2005 at http://www.ag.arizona.edu /azmet/locate.html.

Arizona Water Commission, 1975, Summary, Phase I, Arizona State Water Plan, Inventory of resource and uses.

B

Bales, J.T., and Laney, R.L., 1992: Geohydrological reconnaissance of the Lake Mead NRA-Virgin River, Nevada to Grand Wash Cliffs, Arizona: USGS Water Resources Investigations Report 91-4158, 29 p.*

Beaver Dam Water Company, 2005, Hydrologic Report for Beaver Dam Water Company, Palms Well No. 2 Registration Number 55-551856 on Assured and Adequate Water Supply. Prepared for Arizona Department of Water Resources.*

D

Diroll, M., and Marsh, D., 2006, Status of water quality in Arizona-2004 integrated 305(b) assessment and 303(d) listing report: ADEQ report.*

E

Environmental Protection Agency (EPA), 2005, Surf Your Watershed: Facility reports, accessed April 2005 at http://oaspub.epa.gov/enviro/ef_home2.water.

_____, 2005, 2000 and 1996, Clean Watershed Needs Survey: datasets, accessed March 2005 at http://www.epa.gov/owm/mtb/cwns/index.htm.

F

Fisk, G.G., Duet, D.W., Evans, C.E., Angernoth, N.K., and Longsworth, S.A., 2004, Water Resources Data, Arizona Water Year 2003: USGS Water-Data Report AZ-03-1.*

G

GEO Consultants, 2001, Hydrologic Study, Assured and Adequate Water Supply, Virgin Mountain Utilities Company, T39N R 16W Portions of Sections 10, 11, 14 and 15, Mohave County, Arizona. Prepared for Arizona Department of Water Resources.*

J

Johnson, L., 1996: Beaver Dam Wash surface water quality intensive survey, Nov. 1993- Sept. 1994: ADEQ report, 22 p.*

K

Konieczki, A.D. and Wilson, R.P., 1992, Annual summary of ground-water conditions in Arizona, spring 1986 to spring 1987: USGS Open File Report 92-54.*

L

Leslie & Associates, 1991, Water Adequacy Report for Beaver Dam Estates. Prepared for Arizona Department of Water Resources.*

M

McCormack, H.F., Fisk, G.G., Duet, N.R., Evans, D.W., Roberts, W.P., and Castillo, N.K., 2002, Water resources data Arizona, water year 2002: USGS Water Data Report AZ-02-1.*

N

Natural Resources Conservation Service (NRCS), 2005, SNOTEL (Snowpack Telemetry) stations: Data file, accessed December 2005 at http://www3.wcc.nrcs.usda. gov/nwcc/sntlsites.jsp?state=AZ.

______, 2005, Snow Course stations: Data file, accessed December 2005 at http://www.wcc.nrcs.usda.gov/nwcc/snow-course-sites.jsp?state=AZ

O

Oregon State University, Spatial Climate Analysis Service (SCAS), 2006, Average annual precipitation in Arizona for 1961-1990: PRISM GIS cover, accessed in 2006 at www.ocs.orst.edu/prism.*

P

Pope, G.L., Rigas, P.D., and Smith, C.F., 1998, Statistical summaries of streamflow data and characteristics of drainage basins for selected streamflow-gaging stations in Arizona through water year 1996: USGS Water Resources Investigations Report 98-4225.*

R

Rowley – Leslie Associates, 1987, Water Adequacy Report for Beaver Dam Resort.

Prepared for Arizona Department of Water Resources.*

T

Tadayon, S., 2004, Water withdrawals for irrigation, municipal, mining, thermoelectric-power, and drainage uses in Arizona outside of the active management areas, 1991-2000: USGS Scientific Investigations Report 2004-5293, 27 pp.*

U

US Army Corps of Engineers, 2004 and 2005, National Inventory of Dams: Arizona Dataset, accessed November 2004 to April 2005 at http://crunch.tec.army.mil /nid/webpages/nid.cfm

US Geological Survey (USGS), 2006, Average annual runoff in the United States, 1951-1980: Data file, accessed March 2006 at http://aa179.cr.usgs.gov/metadata /wrdmeta/runoff.htm.*

_____, 2006, Springs and spring discharges: Dataset, received November 2004 and January 2006 from USGS office in Tucson, AZ.*

_____, 2006, National Hydrography Dataset: Arizona dataset, accessed at http://nhd.usgs.gov/.*

_____, 2005, National Water Information System (NWIS): Arizona dataset, accessed December 2005 at http://waterdata.usgs.gov/nwis.*

_____, 2004, Southwest Regional Gap analysis study- land cover descriptions: Electronic file, accessed January 2005 at http://earth.gis.usu.edu/swgap.*

_____, 1981, Geographic digital data for 1:500,000 scale maps: USGS National Mapping Program Data Users Guide.*

V

Valencia, R.A., Wennerlund, J.A., Winstead, R.A., Woods, S., Riley, L., Swanson, E., and Olson, S., 1993, Arizona riparian inventory and mapping project: Arizona Game and Fish Department.*

W

Wahl, C.R., Boe, S.R., Wennerlund, R.A., Winstead, R.A., Allison, L.J., Kubly, D.M., 1997, Remote sensing mapping of Arizona intermittent stream riparian areas: Arizona Game and Fish Technical Report 112.*

Water Infrastructure Finance Authority of Arizona (WIFA), 2005, Clean Watershed Needs Survey-2004: Unpublished data sheets, received July 2005.

Western Regional Climate Center (WRCC), 2005, Pan evaporation stations: Data file accessed December 2005 at http://www4.ncdc.noaa.gov/cgi-win/wwcgi.dll?wwDI~GetCity~USA.

_______, 2005, Precipitation and temperature stations: Data file, accessed December 2005 at http://www4.ncdc.noaa.gov/cgi-win/wwcgi.dll?wwDI~GetCity~USA.*

Wilson, R.P., 1992, Summary of groundwater conditions in Arizona 1985 to 1986: USGS Water Resources Investigation Report, 90-4179.*

*All references marked with an asterisk contain information that was directly used in the basin summaries, tables or maps.

Supplemental Reading

Andersen, Mark, 2005, Assessment of water availability in the Lower Colorado River basin: in Conservation and Innovation in Water Management: Proceedings of the 18th annual Arizona Hydrological Society Symposium, Flagstaff, Arizona, September, 2005.

Arizona Department of Water Resources, 1993, Water resource study Virgin River Basin: Arizona Department of Water Resources Unpublished Report.

Arizona Department of Environmental Quality, 1995, Beaver Dam Wash surface water quality intensive survey, November 1993- September 1994: ADEQ Open File Report 95-4.

Bales, J.T., and Laney, R.L., 1992, Geohydrologic reconnaissance of Lake Mead National Recreation area: Virgin River, Nevada to Grand Wash Cliffs, Arizona: USGS Water Resources Investigations Report 91-4185, 29 p.

Bio/West Inc, 1995, Virgin River geomorphic and hydrological studies related to channel forming flows: Utah Division of Wildlife Resources Report.

Black, K.R. and Rascona, 1991, Maps showing groundwater conditions in the Virgin River basin, Mohave County, Arizona, Lincoln and Clark Counties, Nevada –1991: ADWR Hydrologic Map Series #22.

Burbey, T.J., and others, 2006. Three-dimensional deformation and strain induced by municipal pumping, part 1: Analysis of field data. Journal of Hydrology 319 (2006)

Bureau of Land Management, 2005, Draft resource management plan and draft Environmental Impact Statement for Vermilion Cliffs National Monument, and the Grand Canyon Parashant National Monument: BLM Arizona Field Office and NPS joint report, 2005.

Carlson, D.D., and Meyer, D.F., 1995, Flood on the Virgin River, January 1989, in Utah, Arizona and Nevada, USGS Water Resources Investigations Report 94-4159.

Dettiger, M., Harrill, J., Schmidt, D., 1995, Distribution of carbonite rock aquifers and the potential for their development, southern Nevada and adjacent parts of California , Arizona and Utah: USGS Water Resources Investigations Report 91-4146, 100 p.

Dixon, G.L., Katzer, T.C., 2005, Geology and hydrology of the Lower Virgin River Valley in Nevada, Arizona and Utah: Virgin Valley Water District report.

Enright, M. 1996. Selected hydrologic data for the Beaver Dam Wash area, Washington County, Nevada, and Mohave County, Arizona, 1991-1995: U.S. Geological Survey Open-File Report 96-493

Fogg, J.L., 1998, Beaver Dam Wash instream flow assessment: Bureau of Land Management, March 1998.

Freilich, Leitner & Carlisle, 2005, Mohave County General Plan: Water Resources Element.

Glancy, P.A. and Van Denburgh, A.S., 1969, Water Resources - Reconnaissance Series Report 51, Water-Resources Appraisal of the Lower Virgin River Valley Area, Nevada, Arizona and Utah, USGS Cooperative Report.

Grand Canyon Wildlands Council, 2002, Arizona Strip springs, seeps and natural ponds: Inventory, assessment and development of recovery priorities: Arizona Water Protection Fund Project 99-074.

Hereford, R., Webb, G., and Graham, S., 2002, Precipitation history of the Colorado Plateau region, 1990 – 2000: USGS Fact sheet 119-02.

Holmes, W.F. and others, 1997, Hydrology and Water Quality of the Beaver Dam Wash Area, Washington County, Utah, Lincoln County, Nevada and Mohave County, Arizona. U.S. Geological Survey Water-Resources Investigation Report 97-4193.

JE Fuller/Hydrology & Geomorphology, Inc., SWCA Consultants, and Water Research Center University of Arizona 1998, Preliminary report on the Arizona Stream Navigability Study for the Virgin River in Arizona: Arizona State Land Department Report.

Johnson, M., 2002, Hydrology and groundwater conditions of the tertiary muddy creek formation in the Lower Virgin River basin of southeastern Nevada, northwestern Arizona: Proceedings from Geological Society of America- Rocky Mountain Section annual meeting May 2002.

Katzer, T., Brothers, K., 1995, To capture a river-water supply development of the Virgin River, Clark County, Nevada, in Water in the 21st century; conservation demand and supply: Proceedings from American Water Resources Association, April 1995.

Laney, R.L., and Bales, J.T., 1996, Geohydrologic reconnaissance of Lake Mead National Recreation Area – Las Vegas Wash to Virgin River, Nevada: USGS Water Resources Investigations Report 96-4033, 44 p.

Langenheim, V.E., Glen, J..M., Jachens, R.C., Dixon, G.L., Katzer, T.C., Morin, R.L., 2000, Geophysical constraints on the Virgin River depression, Nevada, Utah amd Arizona: USGS Open File Report 00-407.

Las Vegas Water District, 1991, Distribution of carbonate rock aquifers and the potential for their development, southern Nevada and adjacent parts of California, Arizona, and Utah: USGS Water Resources Investigations Report 91-4146.

Metcalf, L., 1995. Ground water – Surface Water Interactions in the Lower Virgin River Area Arizona and Nevada. M.S. Thesis Department of Geoscience – University of Nevada – Las Vegas

National Park Service, 1990, Simulation of groundwater flow and water level declines that could be caused by proposed withdrawal, Navajo Sandstone, southwestern Utah and northwestern Arizona: USGS Water Resource Investigations Report 90-4105.

Prudic, D.E., and others, 1995, Conceptual Evaluation of Regional Ground-Water Flow in the Carbonate-Rock Province of the Great Basin, Nevada, Utah, and Adjacent States, U.S. Geological Survey Professional Paper 1409-D

Robertson, F.N., 1991, Geochemistry of groundwater in alluvial basins in Arizona, and adjacent parts of Nevada, New Mexico and California: USGS Professional Paper 1406-C, 90 p.

Southern Nevada Water Authority, 2000, Analysis of Gains and Losses in Virgin River Flow Between Bloomington, Utah and Littlefield, Arizona.

Towne, D., 1997, Ambient groundwater quality of the Virgin River basin: a 1997 baseline study: ADEQ Open - File Report 99-4.

Trudeau, D., Hess, J., and Jacobson, R.., 1983, Hydrogeology of the Littlefield Springs, Arizona: Ground Water, Vol. 21, No. 3, May-June 1983

United States Geological Survey, 1997, Hydrology and water quality of the Beaver Dam Wash area, Washington County, Utah, Lincoln County, Nevada, and Mohave County, Arizona: USGS Water Resource Investigations Report 97-4193.

Virgin Valley Water District, 2005, Geology and hydrology of the Virgin River Valley in Nevada, Arizona and Utah.

Warner, S., 2003, Using GPS to Quantify Three Dimensional Storage and Aquifer Deformation in the Virgin Valley River, NV, M.S. Thesis in Geosciences, Virginia Polytechnic Institute and State University.

Washington County Water Conservation District, 1993, The Virgin River: the Lifeblood of Progress-Past, Present and Future.

Zohdy, A.A.R., and others, 1994, A Direct-Current Resistivity Survey of the Beaver Dam Wash Drainage in Southwest Utah, Southeast Nevada, and Northwest Arizona, U.S. Geological Survey Open-File report 94-676

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ACRONYMS AND ABBREVIATIONS

ACC	Arizona Corporation Commission
ADMMR	Arizona Department of Mines and Mineral Resources
ADWR	Arizona Department of Water Resources
ADEQ	Arizona Department of Environmental Quality
AGFD	Arizona Game and Fish Department
ALERT	Automated Local Evaluation in Real Time
ALRIS	Arizona Land Resource Information System
AMA	Active Management Area
AMP	Adaptive Management Program
AMWG	Glen Canyon Adaptive Management Work Group
AWPF	Arizona Water Protection Fund
AZMET	Arizona Meteorological Network
BIA	United States Bureau of Indian Affairs
BLM	United States Bureau of Land Management
C-Aquifer	Coconino Aquifer
CAP	Central Arizona Project
CERCLA	Comprehensive Environmental Response Compensation and Liability Act
CLIMAS	Climate Assessment for the Southwest
DES	Arizona Department of Economic Security
DOD	United States Department of Defense
EIS	Environmental Impact Statement
EPA	Environmental Protection Agency
ESA	Endangered Species Act
GIS	Geographic Information System
gpcd	Gallons per capita per day
gpm	Gallons per minute
GWSI	Groundwater Site Inventory System
HIA	Historically Irrigated Acres
HSR	Hydrographic Survey Report
HUC	Hydrologic Unit Code
ITCA	Intertribal Council of Arizona
LDIG	Local Drought Impact Group
LUST	Leaking Underground Storage Tank
maf	Million acre-feet
M&I	Municipal and Industrial
NHD	National Hydrography Dataset
NOAA	National Oceanic and Atmospheric Administration
NPS	United States National Park Service
NRCD	Natural Resources Conservation District
NRCS	Natural Resources Conservation Service
NWIS	National Water Information System
NWS	National Weather Service
Pan ET	Pan Evaportranspiration

PDO	Pacific Decadal Oscillation
R-Aquifer	Redwall-Muav Aquifer
SNOTEL	SNOpack TELemetry
TDS	Total Dissolved Solids
USBOR	United States Bureau of Reclamation
USDA	United States Department of Agriculture
USDOI	United States Department of Interior
USFS	United States Forest Service
USFWS	United States Fish and Wildlife Service
USGS	United States Geological Survey
VRP	Voluntary Remediation Program
WIFA	Water Infrastructure Finance Authority
WQARF	Water Quality Assurance Revolving Fund
WRCC	Western Regional Climate Center
WWTF	Wastewater Treatment Facility
WWTP	Wastewater Treatment Plant

Appendix A

Appendix A
Arizona Water Protection Fund Projects in the Western Plateau Planning Area through 2005[1]

WESTERN PLATEAU PLANNING AREA				
Groundwater Basin	**Map Number**	**AWPF Grant #**	**Project Title**	**Project Category**
Coconino Plateau	**94**	96-0019	Response of Bebb Willow to Riparian Restoration	Stream Restoration
Coconino Plateau	**230**	99-071	Protection of Spring and Seep Resources of the South Rim, Grand Canyon National Park by Measuring Water Quality, Flow, and Associated Biota	Research
Coconino Plateau	**233**	99-074	Proposal to Inventory, Assess, and Recommend Recovery Priorities for Arizona Strip Springs, Seeps, and Natural Ponds	Research
Coconino Plateau	**252**	99-093	Coconino Plateau Regional Water Study	Research
Coconino Plateau	**313**	05-131	Management & Control of Tamarisk and Other Invasive Vegetation at Backcountry Seeps, Springs, and Tributaries in Grand Canyon National Park	Exotic Species Control
Kanab Plateau	**83**	96-0004	Hydrologic Investigation & Conservation Planning: Pipe Springs	Research
Kanab Plateau	**214**	98-061	Watershed Enhancement on the Antelope Allotment	Upland Water Developments
Kanab Plateau	**234**	99-075	Glen and Grand Canyon Riparian Restoration Project	Exotic Species Control & Revegetation

Source: ADWR 2005f

[1] A map with all Arizona Water Protection Fund grant locations can be found in Volume 1, Appendix C

Appendix B

APPENDIX B
Rural Watershed Partnerships in the Western Plateau Planning Area (2005)

MULTI-PLANNING AREA - Eastern Plateau, Western Plateau and Central Highlands

Watershed Partnership	Primary Participants	Projects & Accomplishments	Issues
Coconino Plateau Water Advisory Council	Flagstaff Coconino County Williams Sedona Page Tusayan TNC Grand Canyon Trust Doney Park Water Co. Navajo Nation Hopi Tribe Havasupai Tribe Hualapai Tribe ADWR ADEQ State Land NRCD NAU USBoR USGS USFS BLM Grand Canyon National Park Glen Canyon NRA NRCS	• 4 categories of potential water augmentation projects have been identified along with their associated costs. • Groundwater study and conceptual model completed • Phase I Water Demand Study for Coconino Plateau • Growth Impacts Study • Western Navajo Pipeline Study • Development of study for importing C aquifer groundwater east of Flagstaff has been completed. • Flagstaff, Hopi and Navajo are exploring cooperative opportunities for developing C aquifer groundwater. • Flagstaff purchased Red Gap Ranch for possible future development of groundwater. • Hopi HSR initiated. • Completed Water Appraisal Study to identify current & future demands and alternatives for meeting projected demands. • Developing numeric model	• Excessive growth throughout entire plateau region • Limited and deep groundwater supplies. • Drought sensitive surface water supplies of Williams, Flagstaff and others • Unsafe dam issues in Williams • Groundwater salinity issues in northeastern part of plateau • Numerous water haulers with few hauling stations that are sometimes cutoff during drought • Unable to get adequate water supply designation under current definition • Growth in Page with no means of additional supply • ESA issues with groundwater usage and impacts on perennial streams • Potential limitation of groundwater usage resulting from reserved groundwater rights of Indians • Uncertainty of Indian water right settlements (LCR & Colorado River) • Proposed San Juan Paiute reservation west of Flagstaff • Potential impacts on springs in Grand Canyon and also on supplies to Havasupai and Hualapai reservations • Access to water development on public lands • Limited groundwater data for entire region • Minor Arsenic issues in Woody Mtn. Well field (9-14 ppb) • Unregulated lot splits • Limited funding resources for planning, projects, infrastructure and studies • Extremely high cost of water augmentation projects

MULTI-PLANNING AREA - Eastern Plateau, Western Plateau and Central Highlands

Watershed Partnership	Primary Participants	Projects & Accomplishments	Issues
Northern Arizona Municipal Water Users Association (NAMWUA)	Prescott Prescott Valley Flagstaff Williams Cottonwood Clarkdale Sedona Payson Chino Valley	• Projected water demands through 2040 have been identified • A request for 70,000 acre-feet of CAP reallocation water has been submitted to ADWR for consideration.	• Limited supplies to meet projected demands • ESA issues impacting potential ground and surface water supplies • Limited funding resources for planning, projects, infrastructure and studies • Competition from Phoenix/Tucson for CAP reallocation water • Funding for Colorado River infrastructure • Water quality issues in Verde Valley and Flagstaff • Upper Basin/Lower Basin issues with Colorado River affect potential for use

WESTERN PLATEAU PLANNING AREA

Watershed Partnership	Primary Participants	Projects & Accomplishments	Issues
Arizona Strip Partnership (Currently not active)	Fredonia Kanab, Utah Colorado City Local citizens ADWR BLM National Park Service USBoR USFS USGS	• Kanab Creek seeps and springs study • Watershed reconnaissance study • Database development	• Brackish groundwater • Inadequate surface water supplies for agriculture • Drought impacts on surface and groundwater supplies • Interstate stream issues • Flooding due to operation of Kanab Creek by Kanab, Utah • Little or no groundwater data available • Limited funding resources for planning, projects, infrastructure and studies